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THE VIRGINIA JOURNAL OF SCIENCE

VOL. I NEW SERIES No. 3

The Impact of Atomic Energy on Education[1]

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Chairman, University Relations Division
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INTRODUCTION

The impact of atomic energy, i.e., the whole field of radiation, on education is not novel. In science, history, sociology, literature, and poetry of the past five centuries, we find that radiation has had an influence on all fields of thought since the early Greeks. The early Egyptians had a name for this, and the Greeks built a temple to the sun. Sun worship has played an important part in the entire history of the race. Many common things today derive from these early practices, such as the naming of the first two days of the week for our principle sources of radiation. Archeologists have discovered many things which early people erected to the sun and the sun gods. From the days of Copernicus and Galileo the sun and its planet children have been the subject of many learned volumes. Without this great source of radiation there would be no civilization on this earth, and we shall probably learn during this century whether we can continue to have a civilization in the presence of these great forces under the control of man.

It is now common knowledge that the atomic explosion of 1945 was the direct result of basic research done, with but vague understanding, during the past century, but with startling significance in the 1930's. From the days of the Alchemists, man has dreamed of the transmutation of the elements and of the possibility of capturing and analyzing the forces which hold the fundamental building blocks of the elements together. Early scientific textbooks taught that the atom was the smallest subdivision of matter. And it was only yesterday that Dalton's atom conceived in 1803 was the basis of chemistry. As late as 1896 many thought that the last word in radiation physics had been spoken. The 1896 catalogue of a prominent university implied this by indicating that future developments would consist primarily of refinement. Shortly thereafter radioactivity was discovered, radium was isolated, and X-rays were discovered.

[1]Presented before the Virginia Academy of Science, Roanoke, May 12, 1950.

Scientific accomplishments in the 1930's made possible a practical and military application of atomic energy: Chadwick in England discovered the neutron; Ernest Lawrence in California invented the cyclotron; Rutherford, Cockcroft, Fermi, and others made notable advances in the transmutations of elements and demonstrated Einstein's law concerning the mass-energy relationship. In 1939, a startling discovery in Germany made practical the atomic bomb. The isotope, U-235, was found to be fissionable. Fortunately, Lise Meitner, then exiled from Germany, correctly interpreted the results of her experiment and even more fortunately she communicated with Niels Bohr. Bohr came to the United States and discussed the startling discovery with Einstein and others. It is doubtless safe to say that very few working on these basic forces of nature had any particular interest up to this time in the practical value of their work. However, when fission became a possibility in the midst of a world war, its practicality was at once apparent. We may be extremely grateful, or regretful depending upon one's point of view, that these physical scientists not only recognized the scientific and practical importance of this discovery but had the ability and the persistence to sell it to our government. From 1939 and until 1942 the bulk of the research in the United States was pure or only slightly applied, although some thought was being given to the engineering problems of atomic bomb production. In June of 1942, President Roosevelt favorably received the recommendation of Bush, Conant, Pegram, and other interested scientists that an atomic bomb was not only feasible but should be developed and produced as early as practical. Shortly thereafter the Manhattan District was formed to carry out all aspects of design, construction, and operation of the necessary production plants, under the direction of General Leslie R. Groves. With the successful detonation of the first atomic bomb in New Mexico in July of 1945, the results of this work became apparent. From this stupendous event there has resulted a "chain reaction" which is being felt in varying degree in every nook and cranny of life, from university hall to the most remote elementary country school. This stems from the fact we now have a new definition of radiation. No longer do we think of it merely as heat from the sun. Our 20th century definition includes the admission of high speed particles in the accompanying phenomenon of radioactivity, radiochemistry, radiophysics, radioisotopes, and radiotherapy. It is this broad definition which must of necessity be applied to radiation today that makes the subject of this paper appropriate for this occasion. It has become very difficult to discover any branch of science which has not felt the impact of this new development. Educational practices and procedures in these fields are likewise affected.

Basically, atomic fission is of greater interest than most atomic reactions, such as slow oxidation or fire, because of the intense amount

and high level of heat and energy which is suddenly released and because of the intense amount and particular characteristics of the radiations which accompany the process. When this energy is released suddenly an atomic explosion results, but when it is released more slowly and under control one has a potential source of power. This is not the place to review the startling and horrible events which have given us quantitative measurements of this power. Our emphasis here is restricted to the peace-time aspects of this problem. The outstanding differences between radiation from an explosion itself and from its fission products is that whereas the instantaneous radiation is over in a fraction of a second, the fission fragments of varying life span continue to emit radiation until they have reached a stable state and are no longer radioactive. It is obvious, therefore, that either of the two great forces, (1) the great heat, and (2) the radiation forces, must have also great possibilities for peace-time uses.

"One of the bright and beneficent by-products of uranium fission has been the radioisotopes, of which there are many. These come either as the direct products of uranium splitting by neutrons in a pile or by subjecting various chemical elements to bombardment by neutrons produced from fission or from any suitable reaction brought about by a beam from any of the high voltage machines like the cyclotron, synchroton, *et al.* Some of these isotopes are too short-lived to be of any practical use but there remains a great variety of useful ones differing widely in radiation, in life period, and in chemical properties. Their variety makes them suitable as tracer elements in chemistry, metallurgy, biology and other sciences as well as in medicine, since some of them also have therapeutic and diagnostic value."[2]

More than 11,000 shipments of radioisotopes have been made from the pile in Oak Ridge, yet the total output for 1949 weighed less than 1/10,000 of an ounce. The container in which a shipment is made weighs more than a billion times that of its contents. One dozen educational institutions in the southern states are using isotopes in research. This new tool is just beginning to be used in our region, but I predict that within a few years every institution of higher learning, especially those offering graduate work, will be using some form of radiation.

At this time, I should like to indicate another educational implication of these recent developments. In December of 1947, almost two years *before* Russia released an alleged atomic blast, the President's Commission on Higher Education made the following statement in a report on "Higher Education for American Democracy"

> "The release of atomic energy that has brought man within sight of world devastation has just as truly brought him the

[2] Lind, S. C. Unpublished manuscript, read as an Introduction to A Symposium on Radiation at the installation of the Tennessee Chapter of the Society of the Sigma Xi, University of Tennessee, April 8, 1950.

promise of a brighter future. The potentialities of atomic power are as great for human betterment as for human annihilation. Man can choose which he will have.

"The possibility of this choice is the supreme fact of our day, and it will necessarily influence the ordering of educational priorities. We have a big job of re-education to do. Nothing less than a complete reorientation of our thinking will suffice if mankind is to survive and move on to higher levels.

"In a real sense the future of our civilization depends on the direction *education* takes, not just in the distant future, but in the days immediately ahead.

"This crisis is admittedly world-wide. All nations need re-education to meet it. But this fact does not lessen the obligation of colleges and universities to undertake the task in the United States. On the contrary, our new position in international affairs increases the obligation. We can do something about the problem in our own country and in occupied areas, and hope that by so doing we will win the friendly cooperation of other nations."

Thus, we see that the educational implications of atomic energy are two-fold; *first,* and most urgent, we must reorient our approach of international affairs. No longer can we entertain the thought of isolationism and no longer can we hesitate to bring the potentialities of this critical situation to the attention of our people. *Secondly,* we must exploit the peace-time values of these new discoveries so that we may demonstrate our willingness and ability to profit by national research installations which are actively developing the peace-time applications of atomic energy. If the educational institutions of the southern region will continue to lend their support to the Oak Ridge National Laboratory I predict that in a very few years it will become the greatest single scientific resource in our higher educational system. It has been gratifying to note the universal acceptance of this resource.

THE IMPACT OF RADIATION ON SUBJECT MATTER FIELDS

Physics.—No science has undergone such rapid and drastic changes in recent years as has the field of physics. C. C. Furnas[3] has noted the altogether bewildering nature of these changes; "The atom which was once the very smallest bit of matter that could exist has now become a menagerie. It first resolves itself into a nucleus and a surrounding swarm of electrical charges. Now the nucleus is too large a unit to be final so the greeting between physicists is: 'What's new in the nucleus?'

"To explain the atom requires ten distinct fundamental physical entities. . . . In reality, the explanations of the atom are only as clear as a thick fog to most of us. Perhaps the atom is unexplainable but

[3] Furnas, C. C.: "On Atoms—Slightly Sarcastic" in A Treasury of Science Harper & Brothers, 1943.

physicists will not admit that.

"Some things have been done to simplify these concepts, but most of them have made the problem to those not thoroughly competent in mathematics still more complicated. It has been found that nothing is absolutely certain. About the best you can say of any future event in this realm is that it is highly probable. Electrons do not seem to care to stay in fixed positions or follow fixed orbits in their atomic structure. They jump from one orbit to another at random, like fleas. They are probably going to be at this spot one-millionth of a second from now, but absolute certainly cannot be assured. Certainty is a thing of the past. The doctrine of cause and effect seems to be a little passé. Yet prediction is still of enough importance that the behaviour of the particles of radiation can be understood by those adequately trained.

"Quantum mechanics and the more recently developed wave mechanics for most of us leave this field in a more hopeless condition than ever, but there are those who seem to thrive on it," and the number of students entering physics, especially nuclear physics, is quite impressive. One hopes that there will be sufficient superiority among them so that enough advanced theory and sufficient application can be found to keep busy those who are less capable. But this game is quite obviously *not* for the amateur. Only the expert can enjoy it.

Thus, while confusing to those uninitiated to the methods of modern physics, one can follow, however remotely, the highly complicated and rugged trail of the physicist, who by the use of this new knowledge of radiation finally leads us to the borderline of knowledge, toward the infinite beyond our galaxy, and toward the infinitesimal in the depths of the nucleus.

Chemistry.—Older textbooks in chemistry often began with a definition of the science. "Chemistry is the study of the composition of matter" or some such sentence. Quoting Irvine Masson, "A science defined is a science dead, a moored hulk; and chemistry is emphatically not that. Truly the margins of this great science fade and fade forever as we move." And chemistry has many margins. The boundary line between physics and chemistry has for many practical purposes disappeared. The impact of radiation on the science of chemistry, while perhaps not as philosophical nor as spectacular as in physics, has nevertheless profoundly influenced every branch of the science.

Among the larger chemical advances of recent times, one of the most important is the electrical character of the chemical atom.[4] This was known not only by a study of the atom's inward parts but from observation of the external properties of the atom and of groups of atoms.

[4] This paragraph based on statements by Dr. Irvine Masson in a chapter on "Chemistry of Today" in Science for a New World, Harper & Brothers, 1943.

It is well to recognize that the assumption of an electrical nature in atoms to explain their chemistry was being made long before anything was definitely known about the internal architecture of an atom. Chemists forgot, or had laid aside, the century-old idea of Berzelius that an atom or a molecule could be a "dipole", that it could have an electro-positive head and an electro-negative tail. Yet, in another form, this is the essence of much of chemistry of recent times. Stated briefly, many pure chemical compounds can be roughly divided, by their behavior, into two sorts. Those of one sort are marked by a great quickness in their mutual reactions; i.e., the component atoms of two different molecules can change one partnership for another with no detectible delay as soon as they are brought together in some suitable medium, usually water. In this class of compounds are acids, alkalies, and salts; i.e., generally the inorganic compounds. On the other hand, substances of the second sort act upon one another more leisurely. Water, which so often serves as a solvent medium for the members of the former class, is less common here except in the natural laboratories of living organisms, but in any case the chemical interactions concerned are sluggish. The greater number of compounds in this class are organic compounds, i.e., compounds of carbon.

When Thomson announced in 1912, that what appeared to be simple atoms frequently consisted of two or more having the same chemical properties but differing slightly in weight, a whole new field of chemistry was laid open.[5] These new chemical elements, differing from their associates only in small amount by weight, were confirmed by Aston's mass spectrograph in 1919. Soddy named them isotopes. It is now known that the nuclei of different atoms of an element all must have the same number of protons, but they may contain different numbers of neutrons, therefore, have different mass numbers. For example, the nucleus of an atom of a heavy isotope of hydrogen, known as deuterium, contains two neutrons. Deuterium is twice as dense as ordinary hydrogen. Water composed of deuterium and oxygen is nearly 2% denser than ordinary water. Dempster, of United States, in 1935 discovered one of the light isotopes of uranium, known as U-235. Since uranium contains 92 electrons in its outer shells, and 92 protons in its nucleus, there must be 145 neutrons in the nucleus in contrast to 146 in normal uranium U-238. It was soon learned that only one isotope U-235 occurred for each 140 of U-238. Since they differ only by such a small amount of weight, one can see the extreme difficulty of separating these two isotopes. Yet this is the basis of our present atomic energy industry. The huge plants at Oak Ridge are built for the purpose of making this separation.

Thus, under the influence of radiation not only have physics and

[5] The paragraph based on Chapter 29, Classical and Modern Physics by Dr. Harvey E. White, D. Van Nostrand Co., Inc., Reprinted 1948.

chemistry moved very close together but a whole new division of these sciences has built up around these basic discoveries.

Today in addition to the great amount of research and applications of the new physics and new chemistry to weapons production, we have an even greater volume in these two fields relating to peace-time applications. In fact, one might characterize the chemistry today as the "chemistry of isotopes."

Biology and Medicine.—Man first observed the release of atomic energy as it occurs naturally in radium and he used the radiations given off by molecular disintegrations to treat cancer and to illuminate watch dials.[6] In 1939, radioactive substances were first produced artificially. Useful amounts of radio-phosphorus, and radio-sodium, were soon applied to the treatment of disease. Biological and medical scientists think of atomic energy in terms of ionizing radiations produced, and the effect they have on living matter. They do not think of the number of calories of heat produced which could be put to work in factories, on ships, and the like. Nor do they think of atomic energy in the terms of an explosive force except as he concerns himself with combatting some of the effects of such explosion in the event of war.

We all have a fair understanding of ionizing radiations. X-rays are a common form. They differ from the gamma rays of radium and the atomic blast chiefly in respect to the wave-length of the energy involved. Other forms of ionizing radiation which you hear about these days include alpha radiations produced by certain natural and artificial radioactive substances and by high energy beams of alpha particles produced in particle accelerator machines. Beta radiation is given off by natural and artificially radioactive substances, and it is also produced by a high energy beam in a betatron. These radiations differ from one another and from X-rays and gamma radiations by having different masses and different energy, the latter dependent upon the source of the particles. Neutron radiations are just what the name implies. Neutrons are given off by uranium and plutonium and are the principle radiations present in an atomic pile.

The effect on living matter of all these types of ionizing radiations is similar to the effects produced by X-rays and radium, so it was natural when these new varieties of ionizing radiation became available that they should be compared with X-rays and gamma rays in established fields of study. One of the principal uses of X-ray and radium, aside from X-ray photography, has been to treat cancer. Before any self-sustaining fission reactions were accomplished, neutron beams had been tried in the treatment of cancer, and radioisotopes have been used both

[6] This section based upon "Peacetime Applications of Atomic Energy" by Dr. Charles L. Dunham, Chief, Medical Branch, Division of Biology and Medicine, U.S. Atomic Energy Commission, February 27, 1950.

to treat cancer and as tracers in the study of human physiology and biochemistry.

Dunham states: "It is rather the exploitation of the ready availability of radioactive forms of the atoms which make up living matter which eventually will have the greatest impact on medical and biological sciences. Thus, the use of radio-iodine and radio-sodium yields much vital data to the practicing physician in areas where many of the cruder and well known techniques fail to furnish definitive information.

"The first biological work utilizing the isotope tracer technique was done with heavy hydrogen shortly after Urey in 1932 discovered how to concentrate this naturally occurring isotope of hydrogen; and Schoenheimer at Columbia University first incorporated heavy hydrogen into some hydrogen-bearing chemical compounds used by the body. By means of very laborious physical chemistry techniques he was able to detect the heavy hydrogen in other chemical compounds recovered from the animal studies, and thus he was able to deduce that certain chemical reactions had taken place in the tissues. The heavy isotope of hydrogen is more stable. It does not disintegrate or decay and give off radiations; it is not radioactive. That is why it was so difficult for Schoenheimer to do his pioneer tracer work. Now we have tritium, with three times the weight of ordinary hydrogen. This isotope is radioactive and lends itself admirably to the extension of the type of work Schoenheimer began."

Thus, biologists and medical research men have available a whole host of labeled chemical compounds. By using these in the feeding of animals and plants and through limited applications to human subjects where the pharmacology is well known, these scientists are building up a tremendous store of data which are being applied to the benefit of mankind. What all of this means in the medical and biological sciences can only be compared to what happened following the discovery of bacteria. The great scourges of mankind soon became a rarity in civilized countries. New and useful discoveries of how living matter behaves are taking place almost every day, thanks to radioactive tracer techniques.

"If man will only give himself half a chance the benefits to be reaped in better health, more productive farms, better materials for industry, and new sources of power can all be had for the asking." (Dunham)

Engineering and Metallurgy.—Major General Kenneth D. Nichols made an excellent summary of this topic in a paper entitled "Education for Nuclear Engineering" read before the Middle Atlantic Section of the American Society of Engineering Education on May 14, 1949.

General Nichols states:

> "Among the many problems which atomic energy forces upon the engineer of today and tomorrow is that of shielding

> against radioactivity with its peculiar problems where one material may shield against one type of radioactivity but not against another. Gadgeteering and remote control for the protection of workmen is also another important responsibility. Carefully and closely controlled methods of chemical recovery of extremely rare and invisible substances and the control of liquid and gaseous waste are but few of the attendant problems facing the engineer . . . the problems presently confronting our universities is to determine what courses should be introduced to train engineers and scientists adequately for the development of atomic energy. Our educational efforts in the field of nuclear engineering should be devoted primarily to giving supplementary education in the fields of physics and radioactivity to engineers rather than to trying to give a little engineering to scientists. Although it is recognized that both approaches are necessary, the engineering approach to the problem of atomic energy will do far more toward expediting solution to the remaining problems than the scientific approach. There is no mystery about atomic energy that good engineering cannot solve."

While some of us might take exception to General Nichols' final statement, it is easy to determine from his paper, as from others which have appeared in this field recently, that a team composed of basic scientists plus engineers will be needed to solve the knotty problems of atomic energy.

Geology.—Atomic energy has given geologists, economic geologists in particular, a new and invigorating challenge.[7] The search for uranium in all countries is far more feverish than was the search for gold in the days of the Spanish explorers or the forty-niners. Today's uranium prospectors, however, are really looking for the proverbial "needle in the hay stack." The universal presence of uranium in small quantities, the background effect of cosmic rays on geiger counters, the illusive character of uranium deposits have all multiplied trouble for the modern prospector. He cannot throw away his pick and shovel nor dispense with his burro, and he must realize that he has probably been preceded by a "flying laboratory" survey, even in the more remote crannies of the earth.

Some evidence of this prospecting activity may be seen in the fact that ore samples submitted to the Raw Materials Division of the AEC by prospectors increased from 400 a month in 1948 to 1200 a month in 1949. Geiger counters have been purchased by the public from private dealers at the rate of 400 a month and the Commission sold over 40,000 copies of its prospector's guide in 1949. Recently, a new type scintillation counter, said to be 100 times more sensitive than any available geiger counter, has been placed on the market. It is difficult to estimate how

[7] See: "Atomic Energy in Relation to Geology" by Commissioner Summer T. Pike, USAEC, March 16, 1949.
"Impact of Atomic Energy on Economic Geology" J. K. Gustafson, Mgr. USAEC Raw Materials Operations, February 16, 1949.

much renewed vigor and added volume of discovery this new instrument may produce.

The knowledge which economic geologists had of uranium-bearing deposits before the release of atomic energy was limited indeed. Some useful techniques were made during the search for radium but the mineralogy of uranium is still far from complete. The paragenesis of uranium mineral suites is poorly understood. About one-half of the known supply of uranium comes from Belgium Congo and most of the remainder is from the Great Bear Lake area of Canada. The geology of these two areas is therefore better known than others, but many details are lacking. The Colorado plateau region is the only significant source of domestic supply yet announced. Here the uranium content of carnotite-bearing sandstones is rather low. Much waste rock must be mined and processed. Intensive work is being done on the concentration of these far-flung low-grade ore bodies.

One of the greatest needs in present uranium exploration is an adequate theory of origin for the deposits occurring in sedimentary rocks. This is especially true of the low-grade carnotite deposits in Colorado and Utah. Economic geologists have long relied upon an adequate theory of origin as a means of locating new ore. Many basic facts are known, but they just do not add up to a convincing theory.

Among many other problems facing geologists are:

(1) The basic mineralogy of uranium occurrence in shales, phosphates, and other marine sediments is still unknown.
(2) There is little understanding of why magnetic differentiation results in a concentration of uranium and thorium in granitic and pegmatitic facies.
(3) The reasons for Pre-Cambrian shield areas being the loci of the world's best high-grade hydrothermal uranium deposits is not understood.
(4) To what extent there may be secondary enrichment of uranium is at best poorly understood.
(5) Whether there is any relationship of helium gas wells to deep uranium deposits is not known.

From these brief sketches of the effect of atomic energy on a few of the major sciences we see that the phrase, "the Atomic Era," has real significance for educators.

THE NATIONAL LABORATORIES OF THE ATOMIC ENERGY COMMISSION

Probably the greatest single educational development in atomic energy was the establishment of national laboratories by the Atomic Energy Commission. The Commission is charged with carrying on an immense amount of basic research in addition to the development of weapons. This results in a large educational increment.

Speaking on "The Role of National Laboratories in Atomic Energy

Development" in Oak Ridge on October 25, 1949, Commissioner Henry D. Smythe points out that the national laboratories of the Commission have three objectives.

> "The *first* is to make more and better weapons. The *second* is to develop possible peace-time uses of atomic energy; and the *third* is to develop such scientific strength in the country as is needed in the long run to support the other two. Success in each of these three objectives requires activity in terms of all three of the functions as cited as necessary for a flourishing science, namely, basic research, applied research, and *teaching*."

I trust that you have noted this emphasis upon teaching. It is this teaching function through special training courses, short courses in definite techniques, extended series of lecturers, symposia, frequent information meetings, etc., which are essential to the primary functions of the national laboratories.

There are five great national laboratories in the Atomic Energy Commission complex. Of these the Oak Ridge laboratory is the most diversified. Another, called Argonne, is administered by the University of Chicago, the Brookhaven National Laboratory on Long Island administered by Associated Universities, Inc., Berkeley Laboratory at the University of California, and Los Alamos in New Mexico. Of these, only the Berkeley Laboratory had a pre-war history. It was well established in the thirties as the largest single installation in nuclear physics. During the war it was converted to isotope separation after the construction of the 184-inch cyclotron had begun and before it was finished. After the war, it has been continued as a research center for nuclear physics and radiochemistry. The Argonne Laboratory grew out of a war laboratory which had been set up for a specific purpose, first to achieve a chain-reaction and then to design the Hanford plant for the production of plutonium. The Brookhaven Laboratory is the only national laboratory founded since the war.

EDUCATIONAL OPPORTUNITIES AT THE NATIONAL LABORATORIES

The well established laboratory at Berkeley and the Argonne Laboratory in Chicago, because of their locations, have many opportunities for the integration of educational procedures not possible at other Commission installations. Thirty or more universities in the mid-western states are within convenient radius of the Argonne laboratory, and when in full operation this laboratory will become a great educational resource. The Los Alamos Laboratory is operated by the University of California but because of its remote location and the highly classified character of its work only a limited number of university staff and graduate students

have participated in its programs. The Hanford (Washington) installation is a production plant and the chief educational activity there is a night graduate school conducted for employees. The Brookhaven National Laboratory is operated by a group of nine large eastern universities. When completed it is expected that the laboratory will be used almost exclusively for educational purposes. The new facility will offer equipment not available in any university and will greatly augment the present advanced status of the nuclear science in the eastern region.

I should like now to direct your attention to the impact of atomic energy on higher education in the southern states extending from the District of Columbia to Texas and Oklahoma. "As you doubtless know, Oak Ridge was selected by the Army as a center of nuclear research on account of its location, favorable in most respects, near enough to centers of science and industry to be readily accessible; near enough to the University of Tennessee to have its support and mutual cooperation, on the Clinch River, and near enough to Knoxville, Norris, and the TVA system to meet the requirements for power, labor, transportation, and commerce. Yet it is remote enough and large enough to be safe. Almost hidden among the ridges and valleys of eastern Tennessee, the huge atomic installations hardly mar the natural beauty of their surroundings.

"Over night Oak Ridge became one of the chief centers of science in the country; not only in science but of its newest and most intriguing branch, the science of the nucleus, fundamentally different from any previously known science. The universities in the South were not slow to appreciate the values of this concentration of science and research facilities in their midst. As soon as the war ended and peace time activities could be resumed, the Oak Ridge Institute of Nuclear Studies was organized to link the scientific research and education in the southern universities to the Oak Ridge laboratories, with the cooperation of the Atomic Energy Commission and the industrial contractors in direct charge of the laboratories.

"The Oak Ridge Institute of Nuclear Studies (chartered as a nonprofit educational organization on October 16, 1946) now has 24 sponsoring university members. In addition to the immediate benefits derived from membership in the Institute, these institutions view the Institute as a regional enterprise of great magnitude and significance. These institutional members of the Institute contribute to its support, and determine its educational policies." (Lind)

It is now evident that our southern instiutions expect to keep up with new developments in the field of nuclear science by sending their staff members and graduate students in ever increasing numbers to the Oak Ridge National Laboratory. Much of the equipment available in this laboratory is prohibitive in cost for any university, and further, it is isolated by law. While I think it quite likely that before long small

reactors will be built by a few universities, nevertheless, there will remain many things in this field which are available only at Oak Ridge.

In the summer of 1949, thirty-six university staff members joined nearly as many research groups in the Oak Ridge laboratories. During 1950, nearly twice this number will participate in these programs. In all cases, teaching and research interest is enriched. Fellowships are available to graduate students on the masters and doctoral levels, and to date 22 applications have been received. So broad and numerous are the problems of nuclear research that there is scarcely a branch of science not represented in Oak Ridge. Graduate students are supervised by a graduate committee with university representation. The meetings of this committee, the presentation and publication of theses, and final examinations are all handled in essentially the normal university manner. Since the problems which the graduate students work on in the laboratory under the Institute's fellowship program are unclassified, immediate publication is possible and the final examination is held on the campus with the laboratory research supervisors serving as members of the examining committee.

Dr. S. C. Lind, formerly dean of the Graduate School and Director of the Institute of Technology at the University of Minnesota and at present Technical Advisor to the Superintendent of the Carbide and Carbon Chemicals Corporation in Oak Ridge and member of the Board of Directors of ORINS stated recently:

> "The stimulation which have been given to scientific research in the South by the cooperation with Oak Ridge and by the formation of its Institute of Nuclear Studies cannot be measured numerically. . . . The fusion of all three laboratories and plants under one management, which took place in 1948, has made possible a more unified attack on research problems and has provided a means for closer cooperation both internally and externally. The Carbide Company, as prime contractor for the operation of all three laboratories in Oak Ridge welcomes the agreement between the Institute, the Commission, and the universities of the South as being advantageous to its research programs, to its employees, and to the educational and scientific interests of the country."

There were 255 registrants in our 1949 summer Symposium on Modern Physics and we expect a great increase for the 1950 Symposium on Modern Chemistry. These symposia are presented by the Oak Ridge National Laboratory and the Institute for university staff members and research workers as up-to-date reviews on modern developments in the several branches of science. The Oak Ridge National Laboratory also conducts a Traveling Lecture Program in cooperation with the Institute. Over 100 laboratory scientists have given over 150 lectures and seminars at southern universities this year. Under a sub-contract with the Institute a Resident Graduate Program is operated by the University of

Tennessee for the employees of local contractors. There have been 2,295 registrants to date, while 480 persons have completed the Institute's special courses in Radioisotope Techniques.

In addition to the above mentioned activities, the Institute operates the American Museum of Atomic Energy and a Medical Division.

CONCLUSION

The goal of all education is the search for truth and the good life. However, in this, the only remaining country which affords individual opportunity and freedom, even we must submit to some restraints. Many of our liberties are restricted for the common good. There are countries with ideologies opposed to our own, which tend to destroy our cherished freedoms—so we have reason to protect and withhold our discoveries from them. All scientists know this is not the ideal way to learn most about the secrets of nature. We know that knowledge may be advanced much more rapidly if workers the world over were permitted a free exchange of ideas. Let us hope that some of us may live to see this dream come true.

Now, we are faced with grim realities. Our enemies know that we have barriers of secrecy against them. They are urging us to give up our basic research and to postpone our developments of atomic energy for useful purposes. May the members of this, the most vigorous and productive of all State Academies of Science, not yield to these demands. Through the united efforts of all men of good will, scientists and non-scientists alike, the impact of atomic energy upon education must be increased until the will for peace shall overcome the will for war. To use the words of Commissioner Gordon Dean:

> "We must so arrange our affairs that we can get precious sleep and rest during an all-night vigil; work while armed; and so balance our program as to assure both an efficient military effort and a rich and rewarding peaceful effort. This country is sufficiently resourceful to do both; but the incentive to do it and the determination to do it will be present only if we continue to keep our eyes fixed on the blessings which are there for us on the far horizons."
>
> "Horizons For Atomic Energy"
> January 11, 1950

The James River Project

SIDNEY S. NEGUS

Long range planning by the Virginia Academy of Science paid a big "dividend" this July 1 when two thousand copies of an 843-page Monograph, *The James River Basin—Past, Present and Future*,* were delivered by the binders.

And this is how it started. During the summer of the year that Wortley F. Rudd was president of the Academy (1940-1941), he conducted a comprehensive survey to determine what the primary objectives of a state academy of science should be and what distinct contributions the Virginia organization should make to the State's welfare over a five-year period. Among the many suggestions received, one by Justus H. Cline of Stuarts Draft appeared to possess unusual merit. It is best described in Mr. Cline's original letter to Ivey F. Lewis.

> "A Monograph on the James River would perhaps appeal to the imagination of Virginians as much as anything the Academy could do. The James is strictly a Virginia River—drains important parts of all the physiographic provinces of the State and embraces practically every stream type. The majority of the important cities and institutions of learning in Virginia are located on it or its tributaries. It varies from almost absolute purity to a very bad degree of pollution in its lower stretches. No stream in the country has more historical romance.
>
> "What civilization has done to this wonderful river, which should be the pride of Virginia and the nation, would certainly be a fine thing for the Academy to find out and tell about. I think the task of securing funds for the undertaking would be relatively simple, and the work would engage a number of the various sections of the Academy."

At the 1940 meeting of the Academy at the Virginia Military Institute, Dr. Rudd proposed the appointment of a Long Range Planning Committee. Having been unanimously authorized, President Rudd's next step was the selection of leading scientists of the State for this important committee. He wisely named Lloyd C. Bird as chairman. He then turned over to this group, prior to its first meeting in October, 1940, the results of his survey. There was unanimous agreement by this Committee that the Cline proposal was one of the best turned up, so it officially recommended at the 1941 meeting at the Medical College of

*May be obtained from Marcellus H. Stow, Lexington, Virginia, or Foley F. Smith, P. O. Box 1395, Richmond, Virginia, for $6.00 a copy postpaid.

Virginia that the Academy prepare a Monograph on the James River. A diagram drawn up in November of 1940 by I. D. Wilson of the Virginia Polytechnic Institute showing how the various public and private agencies of the State might cooperate in tackling the project had a great deal to do with the Committee's recommendation receiving unanimous approval.

It is of interest that the original Committee appointed by the Long Range Planning Committee in 1941 to plan the compilation and publication of the Monograph remained intact throughout the nine years of struggle ahead. It was composed of Robert P. Carroll of the Virginia Military Institute, Justus H.Cline of Stuarts Draft, Ivey F. Lewis of the University of Virginia, Foley F. Smith of Richmond, I. D. Wilson and Marcellus H. Stow of Washington and Lee, Chairman. A. B. Massey of the Virginia Polytechnic Institute and Charles T. O'Neill of Charlottesville were appointed to the Committee in 1947.

And this is how it progressed. Some of the important facts concerned will be listed briefly in chronological order.

1. January, 1942: Chairman Stow called to Washington as Deputy Director of the Mining Division of the War Production Board.
2. February, 1942: The General Assembly of Virginia appropriated $5,000 "to provide for the publication of a volume relating to the James River area of the State."
3. During 1942, W. Catesby Jones, as Chairman of a Finance Committee for the James River Project, raised $133.55 for incidental expenses.
4. May, 1942: A comprehensive report of the James River Project Committee was presented by Dr. Stow at the Academy meeting in Roanoke. Titles and authors of the twenty originally proposed chapters for the Monograph were listed. But in the report were these two significant statements: "When original plans (for the Monograph) were laid, Pearl Harbor was a little known harbor in the Pacific Ocean. When it flared into flames, the lives of all of us were changed so I am afraid the publication of the Monograph will be delayed." And so it was.
5. May, 1943: Dr. Stow reported as president of the Academy at its meeting in Richmond: "The Chairman of the James River Project sent out two letters to the authors of chapters of the Monograph on the James River and was pleased to receive replies from all to the effect that there is no lack of interest in the project, but unfortunately the war has directly or indirectly postponed the date of completion of the work."

6. February, 1944: The General Assembly of Virginia voted to continue the appropriation of $5,000 for the publication of the Monograph for another two years.
7. May, 1944: "No additional chapters to the Monograph have been completed during the past year."
8. May, 1945: The Chairman of the James River Project reported that the future of the project was uncertain because of conditions beyond anyone's control. Dr. Stow offered to turn over to some other Academy member the Chairmanship of this important Committee, because of his duties in war work, but his suggestion met with no enthusiasm whatsoever. Instead he was complimented for "keeping the fire burning."
9. December, 1945: Dr. Stow's duties with the War Production Board were terminated.
10. February, 1946: The General Assembly of Virginia voted again to continue the $5,000 appropriation for the publication of the Monograph.
11. May, 1946: James River Project Committee met and unanimously decided to "pick up loose ends" and go ahead with the completion of the Monograph.
12. December, 1946: Letters were mailed to all authors of proposed chapters asking, first, if they planned to resume work on their assignments, second, if such work could be completed by October 1, 1947, and third, if they would attend a meeting of the group in Richmond early in 1947. Replies indicated that a few wished to be released from their former commitments, but the majority stated they would continue the work and would attend the conference.
13. April 5, 1947: This was the "comeback" day. Forty leaders in various fields throughout the State met in Richmond to discuss with the James River Project Committee the purpose of the Monograph and the style in which the subject matter should be presented. It was agreed that the main objective should be to show what man has done to the James River Basin during his occupancy of it, what is known about existing conditions in the Basin, what brought about these conditions, what has been the development of the various sciences in the Basin, and what are the significant scientific problems that require further investigation. It was emphasized that the project should *not* be involved with what somebody may be interested in doing *to* the James River Basin; it should be concerned solely with presentation of factually accurate information. The group also agreed that the Monograaph should be written in nontechnical style but not over-popularized. Dr. Stow presented the new line-up of those

who had accepted responsibility of writing chapters as of April 3, 1947. It was decided that all chapters must be completed and in the hands of the Chairman by May 1, 1948. At the close of this most encouraging meeting, Dr. Stow posed this question: "Does this group feel, from what has been discussed this afternoon, that a Monograph of this type can be compiled and presented in a style which will be satisfactory to scientists and at the same time instructive to laymen?" The unanimous answer in the affirmative put the Monograph squarely back on its feet again.

14. January, 1948: Among the many conferences held, the one with representatives of the railroads of Virginia is reported to have been outstanding in its enthusiasm about the project.
15. March, 1948: The General Assembly of Virginia appropriated $10,000 to the State Conservation Commission for publication of the Monograph.
16. May, 1948: At the Academy meeting in Roanoke, Dr. Stow reported the status of each chapter of the Monograph. Many had already been completed. He also reported that under Charles T. O'Neill, $800.00 had been raised by the Project's Finance Committee to meet incidental expenses such as postage, prepublication announcements, and publicity items.
17. May, 1949: At the Academy meeting in Richmond, the James River Project Committee packed a lot of information and hard work into the following statement, "It is a pleasure to report that the Monograph on the James River is approaching publication status." A report on each chapter was again presented to the membership of the Academy with a concluding paragraph: "It is hoped that the next annual report of the Chairman of the James River Project Committee will include a statement to the effect that the Monograph on *The James River Basin—Past, Present and Future* has been published."

And this is how it ended. A story about the Committee's race against time during the past year to fulfill the above prediction should some day be recorded and especially by Foley F. Smith. The last day of the "race" is somewhat of a sample of what went before. Dr. Stow was scheduled to make his 1950 annual report for the James River Project Committee to the general meeting of the Academy at Roanoke College on May 12 at about 10:00 p. m. At 9:30 p. m., his prediction of 1949 had not come true. But he had arranged for Richard McDonald, a student at Washington and Lee University, to drive to the binders in Baltimore and pick up a few copies and rush them in his private car to

Roanoke. The Albrecht Company cooperated, and with some of its men working all night, was able to finish binding a few copies. Mr. McDonald arrived with them in Roanoke at about 9:45 p. m. Dr. Stow, while presenting his report a few minutes later, had a copy in his hand. At the close of his report, he presented this copy number one to Justus H. Cline, and copy number two to Doctor Rudd, the men to whom the Monograph is dedicated. They were very happy and so were members of the James River Project Committee.

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SEABOARD AIR LINE RAILWAY COMPANY

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Director of Public Relations
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Deterioration of Green Wood Along Steel-Nail Shank and Its Influence on the Nail-Holding Properties

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SYNOPSIS

Green or partially air-dry wood, in long-time contact with steel nails before or during air-seasoning, may deteriorate along the nail shank without any visual evidence of deterioration at the wood surface under normal conditions of air-seasoning. This deterioration may be considerably more detrimental to the holding properties of plain-shank than to those of the helically grooved Screwtite and the annularly grooved Stronghold nails which have been subjected to extensive tests.

Proper surface coating of the steel-nail shank in long-time contact with green or partially air-dry wood may prevent or decrease wood deterioration. Thus, the long-time properties of steel nails driven into green wood may be improved.

INTRODUCTION

Despite many disadvantages associated with the use of green wood, such wood is employed to a considerable extent for the construction of small and large products ranging from boxes and crates to housing frames and false-work. In most cases where green wood is used, nails are employed to joint the assembly pieces and to hold them together before, during, and after seasoning of the wood. Hence, satisfactory withdrawal resistance and lateral load-carrying capacity of nails both immediately after driving into green wood and after its seasoning may be prime assets for the manufactured product or the respective structure.

According to information given in the "Wood Handbook" (U. S. Department of Agriculture, 1935), the withdrawal resistance of plain-shank steel nails driven into green wood and tested after seasoning may be considerably smaller than the withdrawal resistance of nails tested immediately after driving into green wood. Data on the delayed withdrawal resistance and delayed lateral load-carrying capacity are erratic and difficult to predict for an individual wood species. The loss in withdrawal resistance of plain-shank nails during seasoning may be small for woods like southern pine and some of the oaks, and large for maple and other oaks. On the other hand, properly grooved nails, when driven into green wood, retain all their holding power during seasoning of the wood.

The above reference statements were subject to investigation during a study of the driving resistance, withdrawal resistance, and lateral load-carrying capacity of 2 to 4-in. long plain-shank, helically grooved Screwtite, and annularly grooved Stronghold nails. These nails were tested immediately after driving them into, or after seasoning of, partially air-dry southern pine, green white oak, and green beech. Since the nails for both test series were driven simultaneously, the combined effects on the properties of nails caused by change in moisture content and time elapsed after driving the nails could be evaluated. Attention was given to influences of nail type, size, point, pilot, steel composition, heat treatment, cement-coating, wood species and density.

This study was performed in the Virginia Polytechnic Institute Wood Research Laboratory under the auspices of the Virginia Polytechnic Institute Research Foundation, Inc., and under the sponsorship of the Independent Nail & Packing Company of Bridgewater, Massachusetts, manufacturer of the tested helically grooved Screwtite and annularly grooved Stronghold nails. The presented data are not directly applicable to nails other than those tested because of design variations of nails from other manufacturers. However, they may be considered representative of improved nails such as were used for this investigation.

DESCRIPTION OF INVESTIGATION

Matched decuple tests were performed on the driving resistance and holding properties of non-hardened or hardened, non-coated or cement-coated, low-carbon-steel or high-carbon-steel, plain-shank, helically grooved or annularly grooved nails with Diamond or V points. The 2½, 3, 3½, and 4-in. long low-carbon-steel nails were made of wires of 0.135, 0.148, 0.162, and 0.203-in. diameters, respectively; while the 2, 2½, 3, and 4-in. long high-carbon-steel nails were manufactured of wires of 0.120, 0.120, 0.135, and 0.177-in. diameters, respectively. The helically or annularly grooved 2, 2½, 3, 3½, and 4-in. long nails had clearances of ⅝, ⅞, 1, 1-⅛, and 1-¼-in., respectively, between heads and rolled-on shapes. Those nails which were tested for their withdrawal resistance or lateral load-carrying capacity were hammer-driven to two-third shank penetration into (1) green white oak with an average moisture content of 46 percent, (2) green beech with an average moisture content of 45 percent, and (3) partially air-dry southern pine with an average moisture content of 20 percent. For performance of the delayed test, they were axially or laterally loaded to the ultimate after (1) 4½- to 7½-month seasoning of the white oak to a moisture content of 8-9 percent, (2) 3-month seasoning of the beech to a moisture content of 10-12 percent, and (3) 5- to 7-month seasoning of the southern pine to a moisture content of 10-11 percent. Tests were performed on driving resistance offered

Table I. -- Grand Averages for Matched Decuple Tests On Driving Resistance, Withdrawal Resistance, and Lateral Load-Carrying Capacity For Plain-Shank, Helically Grooved, and Annularly Grooved Nails In Green White Oak, Green Beech, and Partially Air-Dry Southern Pine

Nail Size Length x Wire Dia. (In Inches)	Nail Type	Wood Species	Driving Resistance Shank Penetration (In Inches)			Withdrawal Resistance For 2/3 Shank Penetration (In Pounds)			Lat. Load-Carrying Cap. For 2/3 Shank Penetration (In Pounds)		
			Plain	Helically Grooved	Annularly Grooved	Plain	Helically Grooved	Annularly Grooved	Plain	Helically Grooved	Annularly Grooved
2" x 0.120"	HC-NH-NC-D	Oak	1.04	----	----	313	---	---	604	---	---
		Beech	0.88	----	----	314	---	---	355	---	---
		SYP	1.08	----	----	205	---	---	406	---	---
	HC-H-NC-D	Oak	1.10	0.92	0.95	394	542	520	544	694	465
		Beech	0.87	0.70	0.75	419	494	416	370	342	347
		SYP	1.18	1.02	1.06	335	500	525	494	571	426
	HC-NH-NC-V	Oak	0.95	----	----	289	---	---	587	---	---
		SYP	1.06	----	----	140	---	---	383	---	---
	HC-H-NC-V	Oak	----	0.86	0.93	---	540	511	---	688	271
		SYP	----	0.91	1.05	---	455	478	---	612	280
$2\frac{1}{2}$" x 0.120"	HC-NH-NC-D	Oak	1.01	----	----	375	---	---	625	---	---
		Beech	0.84	----	----	468	---	---	511	---	---
		SYP	1.16	----	----	198	---	---	393	---	---
	HC-H-NC-D	Oak	1.06	0.88	0.96	471	658	662	398	497	518
		Beech	0.83	0.68	0.75	520	719	688	445	464	497
		SYP	1.18	1.01	1.09	380	600	619	356	563	415
	HC-NH-NC-V	Oak	0.91	----	----	374	---	---	612	---	---
		SYP	1.01	----	----	181	---	---	357	---	---
	HC-H-CC-D	Oak	----	0.91	0.90	---	652	662	---	708	391
		Beech	----	0.73	0.71	---	711	680	---	561	328
		SYP	----	1.13	1.09	---	630	576	---	756	403
	HC-H-NC-V	Oak	----	0.87	0.90	---	657	---	---	922	213
		SYP	----	0.92	1.01	---	533	---	---	551	207
	HC-H-NC-D-P	Oak	----	0.89	0.93	---	623	668	---	591	502
		Beech	----	0.69	0.72	---	674	644	---	567	294
		SYP	----	0.99	1.00	---	535	607	---	745	275

		Beech	0.69	0.72	---	674	644	---	567	294		
		SYP	----	0.99	1.00	---	535	607	---	745	275	
$2\frac{1}{2}$" x 0.135"	LC-NH-NC-D	Oak	0.93	0.73	0.72	401	645	732	700	799	597	
		Beech	0.77	0.62	0.60	462	627	704	355	483	638	
		SYP	1.08	0.86	0.82	264	331	644	500	751	620	
	LC-NH-CC-D	Oak	0.93	----	----	515	---	---	732	---	---	
		Beech	0.76	----	----	492	---	---	421	---	---	
			1.12	----	----	438	---	---	638	---	---	
3" x 0.135"	HC-NH-NC-D	Oak	0.85	----	----	408	---	---	773	---	---	
		Beech	0.49	----	----	502	---	---	577	---	---	
		SYP	1.06	----	----	243	---	---	467	---	---	
	HC-H-NC-D	Oak	0.89	0.73	0.75	629	829	785	1178	1373	748	
		Beech	0.53	0.35	0.40	702	841	851	685	681	742	
		SYP	1.08	0.91	0.97	588	784	796	976	1252	782	
3" x 0.148"	LC-NH-NC-D	Oak	0.75	0.63	0.60	541	688	866	906	1071	1080	
		Beech	0.69	0.54	0.54	623	737	868	676	820	769	
		SYP	0.90	0.75	0.75	366	362	825	567	830	1059	
$3\frac{1}{2}$" x 0.162"	LC-NH-NC-D	Oak	0.68	0.56	0.56	663	929	1072	1081	1178	1235	
		Beech	0.61	0.47	0.47	795	946	959	630	881	925	
		SYP	0.80	0.67	0.64	429	609	1015	678	994	1198	
4" x 0.177"	HC-NH-NC-D	Oak	0.62	----	----	834	---	---	1741	---	---	
		Beech	0.50	----	----	1061	---	---	1224	---	---	
		SYP	0.70	----	----	491	---	---	914	---	---	
	HC-H-NC-D	Oak	0.64	0.50	0.55	1100	1444	1397	2106	2559	1345	
		Beech	0.49	0.40	0.45	1232	1291	1273	1415	1522	1513	
		SYP	0.74	0.53	0.61	792	1112	1100	1624	1939	1353	
4" x 0.203"	LC-NH-NC-D	Oak	0.54	0.47	0.46	815	1093	1487	1743	1989	2031	
		Beech	0.44	0.38	0.34	1093	1159	1256	1215	1595	1690	
		SYP	0.64	0.54	0.53	403	664	1170	949	1545	1550	

LC, Low-Carbon Steel; HC, High-Carbon Steel; NH, Non-Hardened; H, Hardened; NC, Non-Coated
CC, Cement-Coated; D, Diamond Point; V, V Point; P, Pilot.

Table II. -- Grand Averages for Matched Decuple Tests on Driving Resistance and Delayed Withdrawal Resistance And for Sextuple Tests on Delayed Lateral Load-Carrying Capacity Of Plain-Shank, Helically Grooved, and Annularly Grooved Nails In Air-Dry White Oak, Beech, and Southern Pine With Nails for Tests on Withdrawal Resistance and Lateral Load-Carrying Capacity Driven into Green White Oak, Green Beech, and Partially Air-Dry Southern Pine

Nail Size Length x Wire Dia. (In Inches)	Nail Type	Wood Species	Driving Resistance Shank Penetration (In Inches)			Withdrawal Resistance For 2/3 Shank Penetration (In Pounds)			Lat. Load-Carrying Cap. For 2/3 Shank Penetration (In Pounds)		
			Plain	Helically Grooved	Annularly Grooved	Plain	Helically Grooved	Annularly Grooved	Plain	Helically Grooved	Annularly Grooved
2" x 0.120"	HC-NH-NC-D	Oak	0.78	----	----	373	---	---	494	---	---
		Beech	----	----	----	173	---	---	542	---	---
		SYP	0.97	----	---	37	---	---	334	---	---
	HC-H-NC-D	Oak	0.85	0.73	0.76	394	[illegible]	716	466	559	510
		Beech	----	----	----	278	616	490	493*	586*	448*
		SYP	1.03	0.91	0.93	91	457	360	473*	633*	292*
	HC-NH-NC-V	Oak	0.73	----	----	413	---	---	603	---	---
		SYP	0.93	----	----	34	---	---	366	---	---
	HC-H-NC-V	Oak	----	0.68	0.75	---	742	668	---	659*	359*
		SYP	----	0.82	0.86	---	440	380	---	690	325*
$2\frac{1}{2}$" x 0.120"	HC-NH-NC D	Oak	0.78	----	----	451	---	---	615	---	---
		Beech	----	----	----	172	---	---	557x	---	---
		SYP	0.96	----	----	50	---	---	327	---	---
	HC-H-NC D	Oak	0.88	0.71	0.76	410	835	712	470*	522*	393*
		Beech	----	----	----	234	816	525	434*	937*	409*
		SYP	0.99	0.84	0.93	110	611	386*	432*	635*	313*
	HC-NH-NC-V	Oak	0.68	----	----	546	---	---	646	---	---
		SYP	0.87	----	----	39	---	---	320	---	---
	HC-H-CC-D	Oak	----	0.76	0.77	---	753	855	---	764	506*
		Beech	----	----	----	---	827	713	---	1019	536*
		SYP	----	0.92	0.93	---	701	508	---	726*	373*
	HC-H-NC-V	Oak	----	0.68	0.70	---	854	695	---	729*	101*
		SYP	----	0.83	0.83	---	523	416	---	712*	243*
	HC-H-NC-D-P	Oak	----	0.70	0.72	---	770	701	---	681*	453*
		Beech	----	----	---	---	769	502*	---	920	323*
		SYP	----	0.84	0.91	---	577	417	---	509*	338*

		Beech	----	----	---	---	769	502*	---	920	323*	
		SYP	----	0.84	0.91	---	577	417	---	509*	338*	
$2\frac{1}{2}$" x 0.135"	LC-NH-NC-D	Oak	0.70	0.59	0.59	383	872	940	640	856	732	
		Beech	0.47	0.39	0.41	227	750	585	692	1036*	877*	
		SYP	0.89	0.74	0.74	77	223	524	415	731	580	
	LC-NH-CC-D	Oak	0.76	----	----	455	---	---	637	---	---	
		Beech	0.53	----	----	190	---	---	596	---	---	
		SYP	0.95	----	----	241	---	---	507	---	---	
3" x 0.135"	HC-NH-NC-D	Oak	0.63	----	----	385	---	---	633	---	---	
		Beech	0.51	----	----	210	---	---	615	---	---	
		SYP	0.92	----	----	68	---	---	331	---	---	
	HC-H-NC-D	Oak	0.68	0.57	0.58	440	1020	1054	914	1306	718*	
		Beech	0.57	0.49	0.49	435	902	726	1214	1361	901*	
		SYP	0.93	0.80	0.85	176	825	538	759	1128	627	
3" x 0.148"	LC-NH-NC-D	Oak	0.54	0.47	0.47	468	1043	1110	780	1159	1111	
		Beech	0.44	0.38	0.38	257	920	845	793	1086	1004	
		SYP	0.80	0.66	0.67	78	224	672	383	721	875	
$3\frac{1}{2}$" x 0.162"	LC-NH-NC-D	Oak	0.53	0.45	0.44	485	1228	1268	892	1407*	1238	
		Beech	0.40	0.36	0.35	306	1072	969	783	1269	1167	
		SYP	0.71	0.57	0.56	85	441	776	496	1033	938	
4" x 0.177"	HC-NH-NC-D	Oak	0.51	----	----	867[x]	---	---	1604	---	---	
		Beech	0.33	----	----	463	---	---	1277	---	---	
		SYP	0.55	----	----	110[x]	---	---	675	---	---	
	HC-H-NC-D	Oak	0.53	0.37	0.42	842[x]	1593[x]	1699[x]	1707	2287	1168*	
		Beech	0.34	0.27	0.31	937	1791	1230	1601	1933	1143*	
		SYP	0.69	0.44	0.52	190[x]	1366[x]	944[x]	1142	1575	934*	
4" x 0.203"	LC-NH-NC-D	Oak	0.41	0.35	0.33	814[x]	1537[x]	1577[x]	1648	2152	1827*	
		Beech	0.29	0.27	0.24	361	1392	1174	1144	1637	1471	
		SYP	0.48	0.47	0.47	105[x]	637[x]	974[x]	715	1549	1201	

LC, Low-Carbon Steel; HC, High-Carbon Steel; NH, Non-Hardened; H, Hardened; NC, Non-Coated; CC, Cement-Coated; D, Diamond Point; V, V Point; P, Pilot

x = True Value Possibly Slightly Larger

* = Shank Failure in One-Half or More Than One-Half of Tests

by planks at the former and latter moisture contents. Grand average nail-holding properties, corrected for non-uniformity in test planks within each species are given in Table I for nails tested immediately after driving into green wood or partially air-dry wood, and in Table II for nails driven simultaneously with the above nails, however, tested after air-seasoning of the wood.

THEORETICAL CONSIDERATIONS

According to the evidence obtained during this investigation, the surface steel of nails driven into green or partially air-dry acid wood slowly changes to hydrated iron oxide ($Fe_2O_3H_2O$) which chemically digests cellulose, and thus weakens the wood surrounding the nail shank. The speed of this process is decreased with the decrease in moisture in the wood. Thus, decomposition of wood may be at a minimum around the steel nail along the relatively dry surface of a green plank, but may be considerably advanced within the plank. Since moisture is principally diffused along the fibers, this decomposition extends to a considerable degree along the grain, while its penetration perpendicular to the grain may be negligible. The initial decomposition of a 3 x 8-in. white oak plank, which took place during a 5-month period of seasoning from 46 to 8-9 percent average moisture content, is shown in Fig. 1. The wood discoloration is attributable to the presence of steel in long-time contact with tannic acid. Holes formed by a non-coated and by a cement-coated annularly grooved steel nail are shown at left and right, respectively. In the center, a hole is shown as formed by a cement-coated annularly grooved steel nail pulled immediately after driving. Because of the lack of any long-time contact between this nail and oak, no discoloration nor decomposition took place.

The presence of rosin acids in green or partially air-dry southern pine may result in partial digestion of the cellulose around a steel-nail shank without any discoloration of the wood. Partial decomposition took place along the holes formed by the annularly grooved steel nails driven into a 3 x 8-in. southern pine plank at an average moisture content of 20 percent and in contact during approximately 5-month seasoning to an average moisture content of 10-11 percent. Since such deterioration is not visible macroscopically, its extent is not shown in Fig. 2.

The limited effectiveness of the resin coating used, as illustrated by its deposition along the nail holes, is demonstrated in the center and right parts of Fig. 2, with more coating deposited by the nail (right) in longer contact with the wood.

Fig. 3 shows the corroded steel-nail surface along the contact area with green oak and the decomposed wood-fiber mass clinging to the grooved nail shanks during withdrawal. These 2½-in. long, 0.135-in.

wire-diameter, low-carbon-steel, plain-shank, helically grooved, and annularly grooved nails were pulled during application of lateral loads along the cantilevered part of the nail shank. Similar corrosion and decomposed oak clinging to the grooved nail shanks are presented in Fig. 4, showing axially loaded, 4-in. long, 0.177-in. wire-diameter, high-carbon-steel, non-hardened plain-shank, hardened helically grooved, and hardened annularly grooved nails after their withdrawal.

The above observations appear to explain the previously cited information given in the "Wood Handbook," since without partial wood decomposition the seasoned wood should have a firmer grip around the nail shank as a result of fiber shrinkage and of fiber stiffening with drying. Since wood decomposition takes place at a relatively slow pace, it may not progress far enough during normal seasoning to digest sufficiently the fibers at a small distance from the nail-shank surface, that is, fibers cantilevering into properly designed nail grooves, to reduce the holding power of nails with satisfactory grooves. Thus, it appears reasonable to expect retention of holding power for satisfactorily grooved nails in most of the wood species during seasoning.

TEST RESULTS

The combined influences of seasoning of wood and of elapsed time after driving the nails on the delayed test properties can be demonstrated by the tabulated over-all percentage variations of these properties from those for nails tested immediately after driving, as presented in Tables III and IV.

TABLE III.—Percentage Variation of Average Delayed Properties For All Tested Nails From Temporary Properties Immediately After Nail Driving

Property	*Wood Species*	*Plain-Shank Nail*	*Helically Grooved Nail*	*Annularly Grooved Nail*
Delayed Withdrawal	White Oak	— 5%	+29%	+21%
	Beech	—52%	+20%	— 7%
	Southern Pine	—73%	— 2%	—22%
	Weighted Av.	—40%	+17%	— 2%
Delayed Lateral Loading	White Oak	—11%	— 0%	— 3%
	Beech	+21%	+49%	+ 7%
	Southern Pine	—21%	— 4%	—18%
	Weighted Av.	— 5%	+14%	— 5%

TABLE IV.—Corresponding Grand-Average Percentage Variation For Matched Non-Coated and Cement-Coated Nails in the Three Wood

Species Tested *Property*	*Nails*	*Plain-Shank Nail*	*Helically Grooved Nail*	*Annularly Grooved Nail*
Delayed Withdrawal	Non-Coated	—48%	+14%	—18%
	Cement-Coated	—39%	+14%	+ 8%
Delayed Lateral Loading	Non-Coated	+12%	+37%	—22%
	Cement-Coated	— 3%	+24%	+21%

INFLUENCE OF TEST VARIABLES

The presented over-all variations in delayed withdrawal resistance and delayed lateral load-carrying capacity from such withdrawal resistance and such lateral load-carrying capacity as observed immediately after nail driving may be broken down with respect to the influences of the investigated design and application variables.

Nail Type.—The efficiencies of grooved nails, in comparison with those of plain-shank nails, tested immediately after driving and after further seasoning of the wood, may be compared if the ratios of corresponding properties for grooved and plain-shank nails are examined. These efficiencies are tabulated in Table V on a percentage basis for non-hardened and hardened, low-carbon-steel and high-carbon-steel, helically and annularly grooved nails, as compared with the respective plain-shank nails.

TABLE V.—Average Relative Efficiency of Grooved Nails During Delayed Testing Compared With That During Testing Immediately After Driving

Property	*Wood Species*	*Non-Hardened Low-Carbon-Steel Helically Grooved Nail*	*Hardened High-Carbon-Steel Helically Grooved Nail*	*Non-Hardened Low-Carbon-Steel Annularly Grooved Nail*	*Hardened High-Carbon-Steel Annularly Grooved Nail*
Delayed Withdrawal	White Oak	+ 56%	+ 49%	+ 53%	+ 54%
	Beech	+207%	+ 89%	+144%	+ 41%
	Southern Pine	+231%	+301%	+471%	+170%
	Weighted Av.	+122%	+ 94%	+ 85%	+163%
Delayed Lateral Loading	White Oak	+ 24%	+ 8%	+ 11%	-------
	Beech	+ 12%	+ 25%	— 6%	-------
	Southern Pine	+ 32%	+ 13%	+ 9%	-------
	Weighted Av.	+ 20%	+ 13%	+ 4%	-------

Nail Size.—Similar comparisons, as made for the various nail types, may be presented for those nail sizes for which directly comparative data were obtained. Thus, in comparison with 2½-in. long nails, the 3, 3½, and 4-in. long *low-carbon-steel nails* of the three types tested, with 10, 20, and 50 percent, respectively, larger shank diameters, offered such percentage efficiencies during delayed testing, if compared with those during testing immediately after driving, as presented in Table VIa.

TABLE VIa.—Average Relative Efficiency of 3, 3½, and 4-in. Long LOW-CARBON-STEEL NAILS During Delayed Testing Compared With That During Testing Immediately After Driving

Wood Species	*During Delayed Withdrawal* Nail Length in Inches				*During Delayed Lat. Loading* Nail Length in Inches			
	2½	3	3½	4	2½	3	3½	4
White Oak	100%	+2%	—9%	— 6%	100%	— 7%	— 6%	—10%
Beech	100%	+4%	±0%	— 6%	100%	—27%	—25%	—47%
Southern Pine	100%	—7%	—4%	+15%	100%	—13%	— 6%	— 7%
Weighted Av.	100%	±0%	—3%	— 2%	100%	—15%	—13%	—23%

Similar comparisons of percentage efficiencies for the 2½, 3, and 4-in. long *high-carbon-steel nails* of the three types tested, with 0, 12.5, and 47.5 percent, respectively, larger shank diameters, in comparison with 2-in. long nails, are recorded in Table VIb.

TABLE VIb.—Average Relative Efficiency of 2½, 3, and 4-in. Long HIGH-CARBON-STEEL NAILS During Delayed Testing Compared With That During Testing Immediately After Driving

Wood Species	*During Delayed Withdrawal* Nail Length in Inches				*During Delayed Lat. Loading* Nail Length in Inches			
	2	2½	3	4	2	2½	3	4
White Oak	100%	—13%	—14%	—19%	100%	+10%	+17%	+ 4%
Beech	100%	—23%	—17%	— 5%	100%	—16%	+ 4%	—28%
Southern Pine	100%	+ 3%	+ 8%	—37%	100%	+ 9%	— 8%	—17%
Weighted Average	100%	—13%	—15%	— 9%	100%	+ 1%	+ 4%	—10%

Nail Point.—In comparison with the Diamond point, the V point of 2 and 2½-in. long, 0.120-in. wire-diameter, high-carbon-steel, non-hardened plain-shank, hardened helically grooved, and hardened annularly grooved nails provided such percentage average efficiencies during delayed testing, if compared with those efficiencies recorded immediately after driving, as presented in Table VII.

TABLE VII.—Average Relative Efficiency of High-Carbon-Steel Nails with V Points During Delayed Testing Compared With That During Testing Immediately After Driving

Property	*Non-Hardened Plain-Shank Nail*	*Hardened Helically Grooved Nail*	*Hardened Annularly Grooved Nail*
Delayed Withdrawal	—21%	— 3%	— 4%
Delayed Lateral Loading	+14%	± 0%	+28%

Nail Pilot.—In comparison with nails without pilots, the 2½-in. long hardened high-carbon-steel helically and annularly grooved nails with 3/16-in. long pilots had, respectively, in all three wood species a 1 and 2 percent smaller average efficiency during *delayed withdrawal* and a 19 percent smaller and a 33 percent greater average efficiency during *delayed lateral loading* than during withdrawal and lateral loading immediately after driving.

Steel Composition.—In comparison with low-carbon-steel nails, the 2½, 3, and 4-in. long high-carbon-steel plain shank nails, with 11.2, 8.8, and 12.8 percent smaller diameters, respectively, had a 7 percent smaller average efficiency during *delayed withdrawal* than during withdrawal immediately after driving. There was no difference in efficiency between *delayed lateral loading* and lateral loading immediately after driving.

Heat Treatment.—In comparison with non-hardened nails, the 2, 2½, 3, and 4-in. long hardened high-carbon-steel plain-shank nails had a 4 percent smaller average efficiency during *delayed withdrawal* and a 2 percent greater average efficiency during *delayed lateral loading* than during withdrawal and lateral loading immediately after driving.

Cement-Coating.—In comparison with non-coated nails, the 2½-in. long low-carbon-steel plain-shank, hardened high-carbon-steel spirally grooved, and hardened high-carbon-steel annularly grooved cement-coated nails provided such percentage average efficiencies during delayed testing, if compared with those efficiencies noted immediately after driving, as listed in Table VIII.

TABLE VIII.—Average Relative Efficiency of Cement-Coated Nails During Delayed Testing Compared With That During Testing Immediately After Driving

Property	Wood Species	Non-Hardened Low-Carbon-Steel Plain-Shank Nail	Hardened High-Carbon-Steel Spirally Grooved Nail	Hardened High-Carbon-Steel Annularly Grooved Nail
Delayed Withdrawal	White Oak	— 7%	— 9%	+20%
	Beech	—21%	+ 2%	+37%
	Southern Pine	+90%	+10%	+42%
	Weighted Average	+ 1%	± 0%	+32%
Delayed Lateral Loading	White Oak	— 5%	+ 3%	+70%
	Beech	+28%	—10%	+98%
	Southern Pine	— 5%	—15%	+23%
	Weighted Average	—13%	—10%	+63%

Wood Species.—In comparison with nails in white oak, the same nails driven into beech and southern pine had a 17 and 24 percent greater average efficiency, respectively, during *delayed withdrawal* than during withdrawal immediately after driving; and an 18 percent smaller and an 8 percent greater average efficiency, respectively, during *delayed lateral loading* than during lateral loading immediately after driving.

Wood Density.—In comparison with nails in an otherwise similar oak plank, nails driven into an 18 percent more dense oak plank had a 16 percent smaller average efficiency during *delayed withdrawal* than during withdrawal immediately after driving.

SUMMARY CONCLUSIONS

1. Typical data on the effectiveness of helically and annularly grooved nails, in comparison with plain-shank nails, (a) immediately after driving and (b) after 3- to 7-month seasoning of the wood, are presented in Table IX.

2. Visual observation and test data indicate that wood, into which steel nails were driven when green, deteriorates during seasoning because of chemical digestion of the cellulose as a result of the formation of hydrated iron oxide in the presence of acids. This deterioration increases with increase in the amount of moisture present; and thus, it may increase with the distance from the plank surface during seasoning. Since it is impossible to impregnate green wood, hence to prevent this deterioration by means of preservative or other treatments from the plank surface, the deterioration of the interior wood may be prevented by properly surface-coating the nail shank. In this way any direct contact between steel and acid in the wood may be eliminated. If green wood is to be

TABLE IX.—Comparison of Effectiveness of Low-Carbon-Steel, Diamond Point, 2½-in. Long, 0.135-in. Diameter Plain-Shank, Cement-Coated Plain-Shank, Helically Grooved Screwtite, and Annularly Grooved Stronghold Nails On Basis of Comparison with Respective Non-Coated Plain-Shank Nail.

Wood Species	*Driven When*	*Tested When*	*Property*	*Non-Coated Plain-Shank Nail*	*Cement-Coated Plain-Shank Nail*	*Non-Coated Helically Grooved Nail*	*Non-Coated Annularly Grooved Nail*
White Oak	Green	Green	Withdrawal Resistance	100%	+ 28%	+ 61%	+ 83%
			Lat. Load-Carrying Capacity	100%	+ 5%	+ 14%	— 15%
Beech	Green	Green	Withdrawal Resistance	100%	+ 6%	+ 36%	+ 52%
			Lat. Load-Carrying Capacity	100%	+ 19%	+ 36%	+ 80%
Southern Pine	Part. Air-Dry	Part. Air-Dry	Withdrawal Resistance	100%	+ 66%	+ 25%	+144%
			Lat. Load-Carrying Capacity	100%	+ 28%	+ 50%	+ 24%
White Oak	Green	Air-Dry	Delayed Withdrawal Resist.	100%	+ 19%	+128%	+145%
			Del. Lat. Load-Carrying Cap.	100%	± 0%	+ 34%	+ 14%
Beech	Green	Air-Dry	Delayed Withdrawal Resist.	100%	— 16%	+230%	+158%
			Del. Lat. Load-Carrying Cap.	100%	— 14%	+ 50%	+ 27%
Southern Pine	Part. Air-Dry	Air-Dry	Delayed Withdrawal Resist.	100%	+213%	+190%*	+581%*
			Del. Lat. Load-Carrying Cap.	100%	+ 22%	+ 76%	+ 40%

*These values increased to +1135% and +873% for 2-in. long, 0.120-in. wire-diameter, hardened, high-carbon-steel, helically grooved Screwtite and annularly grooved Stronghold nails and to +1122% and +672% for 2⅛-in. long, 0.120-in. wire-diameter, hardened, high-carbon-steel, helically grooved Screwtite and annularly grooved Stronghold nails, respectively.

used and if optimum nail-withdrawal resistance is an important factor during and after seasoning of the wood, it may be advisable to use only such properly coated nails.

3. An increase in withdrawal resistance and lateral load-carrying capacity of nails might be visualized during seasoning of wood as a result of shrinkage and stiffening of the wood fibers around the nail shank. Seventeen to 20 percent increases could be observed in average resistance to driving of plain-shank, helically grooved, and annularly grooved nails into the tested wood species. In spite of these two observations, and doubtlessly as a result of deterioration of wood around the nail shank, the average observed withdrawal resistance of plain-shank nails decreased during seasoning 5 percent in white oak, 52 percent in beech, and 73 percent in southern pine. On the other hand, the average withdrawal resistance of helically grooved nails increased 29 percent in white oak, 20 percent in beech, and decreased only 2 percent in southern pine; and that of annularly grooved nails increased 21 percent in white oak, however, decreased 7 percent in beech and 22 percent in southern pine. Similarly, the lateral load-carrying capacity of plain-shank, helically grooved, and annularly grooved nails decreased during seasoning of white oak and southern pine, but increased during seasoning of beech, with the plain-shank nails in white oak and southern pine showing maximum decreases in average lateral load-carrying capacity. Thus, deterioration of wood around the nail shank during seasoning of wood is considerably more detrimental to the holding properties of plain-shank than to those of the tested helically and annularly grooved nails.

4. Cement-coating, as applied to the tested nails, tended to reduce the decrease in withdrawal resistance during seasoning. A more satisfactory and continuous coating with better adhesion to the steel surface might have resulted in better nail-withdrawal resistance.

5. In comparison with plain-shank nails, helically and annularly grooved nails offer somewhat increased driving resistance. However, this increase is combined with considerably increased withdrawal resistance and lateral load-carrying capacity. Thus,

(a) An approximately 15 percent increase in average driving resistance, over that for corresponding plain-shank nails, can be expected for helically and annularly grooved nails if driven into air-dry white oak, beech and southern pine, and only slightly greater increases if driven into these species when green or partially air-dry;

(b) With the above small increase in average driving resistance, 12 to 72 percent increases may be expected for the average withdrawal resistance of helically and annularly grooved nails, over that of corresponding plain-shank nails, driven into the above green or partially air-dry wood species, with these percentage values increasing to 58 and 757 percent during 3 to 7-month seasoning of the wood;

(c) Similarly, 3 to 64 percent increases in average lateral load-carrying capacity of helically and annularly grooved nails, over that of corresponding plain-shank nails, driven into the above green or partially air-dry species increase to 29 to 101 percent during 3 to 7-month seasoning of the wood.

6. With increase in length of steel nails, somewhat smaller increases in their driving resistance, withdrawal resistance, and lateral load-carrying capacity, than determined for nails driven into green wood, are shown after seasoning of the wood. This is the result of the greater inside than surface deterioration of the wood.

7. If the nails are driven into green white oak, beech, and southern pine and tested either immediately after driving or after air-seasoning of the wood, driving resistance, withdrawal resistance, and lateral load-carrying capacity are not appreciably affected by V points, in comparison with Diamond points; by 3/16-in. long pilots for grooved nails; by high-carbon content, in comparison with low-carbon content of steel; and by heat-treatment.

8. Cement-coating may also not appreciably affect the above properties if the nails are tested either immediately after driving into green wood or after its air-seasoning, with the exception of plain-shank nails in southern pine, where cement-coating improved the withdrawal resistance immediately after driving 65 percent and after seasoning 213 percent. Furthermore, cement-coating had no appreciable effect on the withdrawal resistance of annularly grooved nails immediately after driving, but appeared to be of somewhat beneficial effect (20 to 32 percent) after seasoning of the three tested species. Also, cement-coating was of disadvantage to the lateral load-carrying capacity of annularly grooved nails immediately after driving (3 to 34 percent) and of beneficial effect after seasoning of the three species (17 to 31 percent).

9. Because of the considerable difference in moisture content, the average driving resistance, withdrawal resistance, and lateral load-carrying capacity of nails in green white oak and beech, on the one hand, and partially air-dry southern pine, on the other hand, did not differ greatly, nor as greatly as would be expected, if the nails were tested in these species with like moisture content.

At air-dry condition, the average resistance of nails to driving into beech was $1\frac{1}{4}$ and into southern pine was $\frac{2}{3}$ of that for nails driven into white oak. The average delayed withdrawal resistance of nails in beech was 4/5 and in southern pine $\frac{1}{2}$ of that of nails in white oak. The average delayed lateral load-carrying capacity of nails in beech was the same and in southern pine was slightly more than 2/3 of that of nails in white oak.

10. In both green and air-dry wood, the driving resistance directly increased with increase in wood density. On the other hand, the with-

drawal resistance, directly increasing with increase in density immediately after nail driving, showed no significant increase with increase in specific gravity during seasoning of the investigated oak plank.

11. Variation in physical structure of the test planks resulted in appreciable variation in properties of nails within the same plank cross-section, these variations being slightly smaller after seasoning of the planks than immediately after driving of the nails.

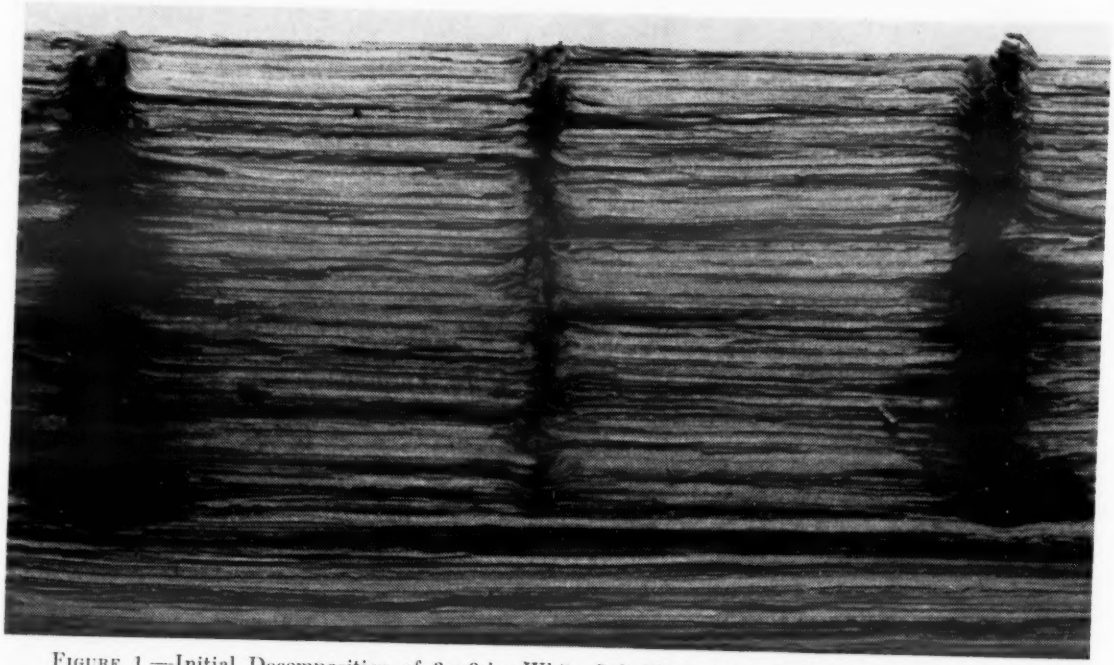

FIGURE 1.—Initial Decomposition of 3 x 8-in. White Oak Plank Along Nail Shanks Within a 5-Month Period of Seasoning from 46 to 8-9 Percent Average Moisture Content. Plainly Visible Because of Discoloration of Wood Attributable to the Presence of Tannic Acid (Twice Actual Size).

FIGURE 2.—Initial Decomposition of 3 x8-in. Southern Pine Plank Along Nail Shanks Within a 5-Month Period of Seasoning from 20 to 10-11 Percent Average Moisture Content, Not Visible Because in the Presence of Rosin Acids Discoloration of Wood Does Not Take Place (Twice Actual Size).

FIGURE 3.—2½-in. Long, 0.135-in. Wire-Diameter, Low-Carbon-Steel, Plain-Shank (Lower), Helically Grooved (Center), and Annularly Grooved (Upper) Nails, Driven into Green White Oak and Withdrawn Upon Lateral Loading After 5-Month Seasoning of the Plank (Full Size).

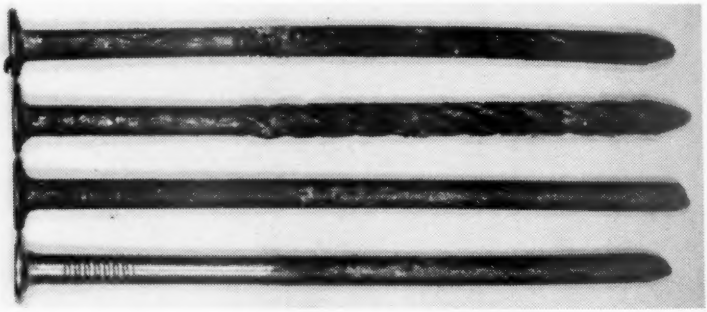

FIGURE 4.—4-in. Long, 0.177-in. Wire-Diameter, High-Carbon-Steel, Non-Hardened (Lower) and Hardened (Second from Bottom) Plain Shank, Hardened Helically Grooved (Second from Top), and Hardened Tnnularly Grooved (Upper) Nails, Driven into Green White Oak, and Withdrawn After 5-Month Seasoning of the Plank (Full Size).

Notes on Some Virginia Millipeds of the Family Polydesmidae

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The following observations on polydesmid millipeds pertain to members of four related genera which occur in Virginia, and have been made more or less incidentally to studies in other groups. Because of their brevity they may be profitably assembled and presented together.

GENUS SCYTONOTUS KOCH[1]

Remarkably enough, the homogeneity of the widespread eastern milliped *Scytonotus granulatus* (Say) has never been questioned by American authors, despite its having been recorded from such distant localities as Iowa, New York, and North Carolina. Considering the small size and, presumably, low degree of vagility of the animal, one would expect considerable manifestation of localized speciation at peripheral portions of the range.

In 1943, H. F. Loomis described *Lasiolathus virginicus* as a new genus and species of milliped, said to be related to *Scytonotus*. Mature specimens were lacking, and generic characters were taken from non-sexual modifications, chiefly degree of dorsal tuberculation, serration of the keels, and setiferous condition of the tergites. Adults of *Lasiolathus* were never found, although the form has been reported from Virginia, Kentucky, and Tennessee. Later, in 1947, I found that *Lasiolathus* was but the immature stage of *Scytonotus,* based on observations made in Alleghany County, Virginia; and in that year published a short paper synonymizing Loomis' genus and species under *S. granulatus.* Since Loomis and I agreed that the Alleghany County immatures were his *L. virginicus,* I created the synonymy on the unfortunate assumption that *granulatus* was the only eastern member of the genus.

While recently examining diplopods taken on the Blue Ridge in Albemarle County, Va., I was surprised to note that the male gonopods of the locally abundant *Scytonotus* differed trenchantly from those of more western specimens. Knowing that the Blue Ridge is populated by a number of endemic species of animals, I suspected that the specimens might be the form described by Loomis. Accordingly a trip was made to the type locality of *L. virginicus*, and a mature male specimen, which

[1] American authors have long referred **Scytonotus** to the family Sphaeriotrichopidae, although Attems, who established the family and described most of its genera, pointed out the error of doing so in 1931 (Zoologica, v. 30, Heft, 79, p. 144).

is herein designated as plesiotype, was obtained. It agrees in every respect with the Albemarle specimens, and it now becomes necessary to revive Loomis' name for this species of the Virginia Blue Ridge.

Perhaps the small size of the animal, and superficial similarity of the male gonopods have contributed to the universal acceptance of the name *granulatus*. I suspect that the latter factor has been largely responsible, for the few published drawings, even those of Cook & Cook (1895, Ann. N. Y. Acad. Sci., 9: fig. 7) appear to be somewhat oversimplified. I have cleared and mounted a number of gonopods, and microscopic study of these reveals that diagnostic characters are abundant and that no appreciable intraspecific variation occurs. For the accompanying drawings, outlines were made from low power magnification (100 x) and details added from higher power observation (430 x).

SCYTONOTUS VIRGINICUS Loomis

Figure 2.

Lasiolathus virginicus Loomis, 1943, Journ. Washington Acad. Sci., 33: 318-320.

Scytonotus granulatus Hoffman, 1947, Proc. Biol. Soc. Washington, 60: 139-140.

Type locality.—Panorama, Thornton Gap, Page-Rappahannock counties, Virginia.

Type specimens.—Immature male holotype in the Museum of Comparative Zoology and immature male paratype in the U. S. National Museum, collected by H. F. Loomis. Adult male plesiotype in my personal collection, collected by Anne K. Brown, Hubert I. Kleinpeter, and Richard L. Hoffman, March 29, 1949.

Records.—I have material of *virginicus* from two places other than the type locality. These are both in the Blue Ridge in Virginia, as follows: *Albemarle Co.*: Sugar Hollow, 6 miles west of Whitehall, October 31, 1947, March 3, 1949, March 21, 1949. *Nelson Co.*: Humpback Mountain, 4 miles south of Afton, November 29, 1948. The range of the species as presently known is approximately the same as that of the recently described xystodesmid milliped *Nannaria morrisoni* Hoffman.

Remarks.—In addition to the obvious differences in the gonopods, *S. virginicus* is further distinct in that the penultimate joints of the male legs are not enlarged and produced as in *granulatus*. As far as overall size and color go, the two species are very similar.

GENUS BRACHYDESMUS HELLER

For several years I have occasionally found specimens of a small polydesmid, which I identified as a member of the genus *Brachydesmus*, in the garden of my residence at Clifton Forge, Alleghany County, Va. On recently having access to Dr. Carl Graf Attems' monumental treatises

on the polydesmoids of the world (Das Tierreich, Lief. 68-70) I identified the animal as a subspecies of *B. superus* described by Attems from Goteborg, Sweden. The citation is as follows.

BRACHYDESMUS SUPERUS SCANDANAVIUS Attems

Figure 3

Brachydesmus superus scandanavius Attems, 1927, Abh. Senckenb. Ges., 39: 263, figs. 26-28; 1940, Das Tierreich, 70: 121, fig. 170.

Attems' figure in the second work cited above is drawn from a gonopod in a somewhat oblique position, and apparently from a magnification too low to show all of the structure properly. The accompanying drawing is made from a gonopod of a Clifton Forge specimen, cleared in KOH and mounted in balsam. High power (430 x) magnification was found necessary.

I find that differences between *scandanavius* and *B. s. elbanus* Attems from the Mediterranean region are very slight, and suspect that the former is perhaps only an individual variation of the latter, transported to Sweden by commerce. For the present, however, it seems possible to separate *scandanavius* by the shorter subpulvillar spine (d) and the slightly more proximal position of the median endspine (i). Also, the denticulations of the gonopod femur (P) are much larger in *elbanus*.[2]

Brachydesmus, as Attems points out, is a Palearctic genus, and I suspect that all of the North American forms described under this name will prove to be but introduced European species, much as Prof. R. V. Chamberlin pointed out, nearly three decades ago (1921) for julid millipeds.

Illustrations of the species named by various American workers leave much to be desired. The best illustrated gonopod, that of *B. pallidus* Loomis (1939: 191) leaves no doubt that the species is a member of the *superus* complex, but even this seems to be drawn without adequate magnification. Another eastern form is *B. dux* Chamberlin (1940: 284) from North Carolina; the drawing of its gonopod engenders doubt that the animal is even a member of the Polydesmidae, for the hairpad said by Attems to be typical of the family is not shown, and the general appearance of the appendage is very unlike that characteristic of *Brachydesmi* and related forms. *B. gladiolus* Williams and Hefner (1928: 113) from Ohio is admittedly like *superus*. It seems to differ from the typical form, but may prove to be one of the subspecies or varieties.

[2] These terms are English equivalents of those used by Attems, and the abbreviations on the drawings of the **Brachydesmus** gonopod are the same as those employed in the Tierreich monograph.

B. s. scandanavius has not been previously reported from this country. It is of some interest that a localized subspecies would be imported instead of one of the widespread forms. Presumably it came to western Virginia in bulbs or other produce before the inauguration of strict quarantine measures.

GENUS PSEUDOPOLYDESMUS ATTEMS

A small member of this genus obtained near Norfolk, Va., during the course of herpetological field work, proves to be undescribed. Judged from the male gonopods, the relationships of this species appear to be with certain southern and midwestern forms, rather than with the widespread *P. serratus* (Say) which occurs in the same region. It may be a northern member of an "Austral" group of species of this genus.

PSEUDOPOLYDESMUS PALUDICOLUS, new species

Figure 4

Type specimen.—Adult male. U.S. Nat. Mus. no. 1871, collected at Sand Bridge, 5 miles south of Virginia Beach, Princess Anne Co., Va., May 8, 1949. L. M. Carter, H. I. Kleinpeter, and R. L. Hoffman, colls.

Diagnosis.—Male gonopods characteristic in the following particulars: femur with a large subpulvillar tooth (d) and a definite endomerite (e) immediately laterad of it, no basal femoral denticulations; tibiotarsus with a broad, two-pointed flangelike process (h) and a large single subterminal tooth (i), surrounded by a tuft of flat bristles.

Description of male type.—A small species, length 13, width, 2.3 mm.; general proportions and configuration of body similar to *P. serratus*. The following points are noteworthy: tergites with only two transverse rows of quadrate areas (the normal first row not differentiated); usually four areas in the anterior row and six in the posterior; edges of keels not denticulated, the caudolateral corners produced caudad rather more noticeably than in other species.

Sternites between the 5th, 6th, 9th, and 10th pair of legs with paired, distally setose processes.

Male gonopods as illustrated (fig. 4).

Color uniform light brown dorsally, somewhat paler on the ventral surface; distal article of antenna piceous.

Remarks.—This description is based on a single individual found under a board on the inner dunes several hundred feet inland from the ocean. The vegetation is chiefly grass and sedge, with a few pines and thickets of *Myrica*. No other diplopods were found, nor any chilopods.

GENUS DIXIDESMUS CHAMBERLIN

This genus of the southern Appalachians is represented in Virginia by a single, very characteristic, species which seems to reach its northernmost limits in this State.

DIXIDESMUS BRANNERI (Bollman)

Polydesmus branneri Bollman, 1887, Proc. U.S. Nat. Mus., 10:620.

At present, the known range of this species is approximately from Gainesville, Florida, and southern Mississippi, north through the Appalachians to central western Virginia. Available local records, arranged from south to north, are as follows:

Smyth-Grayson cos.—Mount Rogers, 5400 feet, July 1-2, 1947. *Tazewell Co.*—Beartown Mountain at Burkes Garden, 4600 feet, June 30, 1947. *Floyd Co.*—Rocky Knob Park, 6 miles S.W. of Floyd, July 3, 1947. *Giles Co.*—Mountain Lake, 3800 feet, June-July, 1947. *Bedford Co.*—Blue Ridge Parkway, south of Apple Orchard Mountain, 3800 feet, March 25, 1948. *Alleghany Co.*—3 miles N. W. of Clifton Forge, 1500 feet, March-October. *Bath Co.*—Warm Springs Mountain, east of Hot Springs, March, 1947; 7.4 miles S.W. of Milboro Springs, Rt. 42, 1300 feet, May 11, 1947. *Rockbridge Co.*—Goshen Pass, 1400 feet, June 16, 1947; west side of Rocky Mountain, Blue Ridge Parkway, August 24, 1949. *Nelson Co.*—Crabtree Falls, June 16, 1948. *Nelson-Augusta cos.*—Humpback Mountain, 6 miles south of Afton, 2500 feet, June 17, 1947.

Collections made farther north along the Blue Ridge in Albemarle County have failed to reveal *branneri*, as have investigations in the Alleghanies north of Hot Springs. Extensive collections from the vicinity of Thornton Gap (in the U.S. National Museum) contain only *Pseudopolydesmus serratus*.

Dixidesmus apparently enjoyed a much wider former range, as suggested by the presence of two species in the mountains of southern New York and adjacent northeast Pennsylvania. Collecting in central Pennsylvania and Maryland would be of interest, to determine whether the present discontinuity is real or only apparent.

As regards habitat, *D. branneri* shows a marked predilection for cool, moist situations such as afforded by high mountains and deep water-gaps. In the southern part of its range, however, a much greater ecological tolerance is shown by the occurrence of the species in the hot lowlands of Georgia and Florida.

Living specimens of *branneri* are immediately distinct in color. The tergites are black with the keels very strikingly brick-red or pink, as opposed to the uniform brown dorsum of *serratus* and other pseudopolydesmids.

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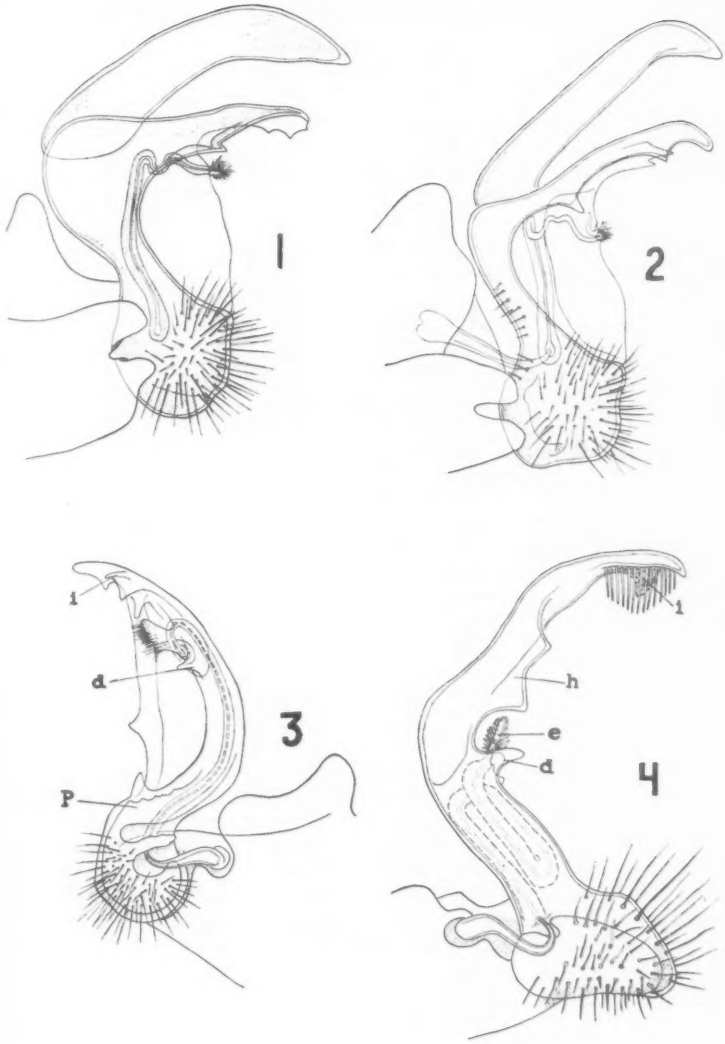
EXPLANATION OF PLATE

Fig. 1. *Scytonotus granulatus* (Say). Mesial view of left gonopod of male from Clifton Forge, Va. Solenite not shown.

Fig. 2. *Scytonotus virginicus* (Loomie). Mesial view of left gonopod of male, Sugar Hollow, Albemarle Co., Va.

Fig. 3. *Brachydesmus superus scandanavius* Attems. Mesial view of right gonopod of male, Clifton Forge, Va., Abbreviations: *d,* subpulvillar tooth; *i,* median end-spine; *P,* femur.

Fig. 4. *Pseudopolydesmus paludicolus* Hoffman. Mesial view of left gonopod of male holotype, Sand Bridge, Va. Abbreviations: *d,* subpulvillar tooth; *e,* endomerite; *h,* tibiotarsal median flange; *i,* subterminal tooth.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Granulosis of the Red-Banded Leaf Roller

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Prior to 1947 no occurrence of the general type of infection known as granulosis had been reported in insects outside of France. In this year Steinhaus[1] made the first discovery of granulosis in the Western Hemisphere by finding it in the variegated cutworm, *Peridroma margaritosa* (Haw.). A year later similar granuloses were found in the salt-marsh caterpillar, *Estigmere acraea* (Drury), and in the buckeye caterpillar, *Junonia coenia* Hub., by Steinhaus and Thompson. All three of these cases occurred in California.

In early August, 1949, while rearing the red-banded leaf roller, *Argyrotaenia velutinana* (Walker), it was noticed that a few larvae differed in color from the normal green or yellow-green coloration. As the season progressed there was an increase in the number of affected larvae. The first indication of an abnormal condition was the appearance of two longitudinal white streaks on the dorsal side, which were clearly visible through the larval cuticula. Later the streaks resembled two chains of irregularly shaped cells with a cluster of darker, inclusion bodies in each cell. After the disease was well developed the larvae became enlarged and sluggish.

Specimens of diseased larvae were examined by Dr. R. G. Henderson[2] who found no evidence of a fungous parasite. Specimens were then sent to Dr. E. A. Steinhaus[3] who identified the disease as a form of granulosis, a virus type of disease in which granular inclusion bodies accumulate in the cytoplasm of certain tissue cells. His identification was based on complete microscopal studies including the examination of preparations from the insect with an electron microscope. He further stated that this is the first recorded occurrence of any granulosis in insects in this country outside of California.

It is planned that more extensive studies of the occurrence of granulosis in the red-banded leaf roller larvae will be made during the coming season. The economic importance of the newly discovered disease would be considerably enhanced if it should be found to effect any appreciable mortality of the host, as the red-banded leaf roller is currently one of the primary insects causing injury to apples. In any event, the discovery of this virus disease in an insect in Virginia represents a material contribution to our knowledge of its geographic distribution.

[1] Steinhaus, Edward A. Principles of Insect Pathology. McGraw-Hill Book Company, Inc. 1949. pp. 500-501.
[2] Plant Pathologist, Virginia Agricultural Experiment Station.
[3] Associate Professor of Insect Pathology, University of California.

The ν_3 Fundamental of Nitrous Oxide

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HISTORICAL BACKGROUND

The first significant investigator of the infrared spectra of N_2O was C. P. Snow who published his results in 1930. His analysis of N_2O included seven vibration bands between 2μ and 7μ. He concluded that these bands were the only ones present when a prism instrument failed to reveal any evidence of a band between 7μ and 15μ. His conclusions stated that N_2O was a linear symmetrical molecule, basing this statement upon the similarity of N_2O to CO_2 and CS_2.

Subsequent work by Plyler and Barker (1931) showed that Snow's investigation was incomplete. Their paper included high resolution of the rotational fine structure of the fundamentals, ν_2 at 17.0μ, and ν_1 at 7.77μ. The band at 4.49μ was only partially resolved and branch outlines were obtained for numerous combination bands.

The work of Plyler and Barker (1931) substantiated the work of Snow (1930) in the respect that the location of the bands studied by both was in agreement. However, the inclusion of the two fundamentals, ν_1 and ν_2, permitted Plyler and Barker to prove quite definitely that the molecular arrangement of N_2O had to be linear but *unsymmetrical*. Thus the molecule has the form N-N-O rather than N-O-N.

APPARATUS

The spectrometer used in this work was the one described by Bell, Noble, and Nielsen (1947) in "The Review of Scientific Instruments", and any questions concerning its operation may be answered by referring to that publication.

The gas cell used was built of polished NaCl windows fastened securely to the ends of a 10 centimeter section of glass tubing approximately 4 centimeters in diameter. A stopcock was sealed into the side of the cell in order to facilitate the introduction of gas at various pressures. The gas was reported to be free of water vapor when purchased but a shallow boat of P_2O_5 was put into the cell as a precautionary measure.

DISCUSSION OF THEORY

The nitrous oxide molecule is triatiomic and linear. Thus one would expect four (3N - 5) degrees of vibrational freedom and consequently four fundamental modes of vibration. However, two of the modes of

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vibration have the same frequency, producing what is called a doubly degenerate mode of vibration. The vibration giving rise to the ν_2 band is of this type. It is also a perpendicular vibration, i.e., one in which the atoms vibrate perpendicularly to the axis of symmetry of the molecule.

The remaining two fundamentals, ν_1 and ν_3, are parallel type bands with the vibrations occurring along the axis of symmetry. There are many other bands in the infrared spectra of N_2O but they are either harmonics of, or combinations of ν_1, ν_2, and ν_3.

Since ν_3 is a parallel vibration it contains only a positive R branch and a negative P branch, the selection rule involving the rotational quantum number, J, being $\Delta J = \pm 1$. ν_1 is also a parallel vibration. However, ν_2 is a perpendicular vibration and can have P, Q, and R branches following the selection rule $\Delta J = 0, \pm 1$. The Q branch, or zero branch, arises from $\Delta J = 0$ transitions.

Since this paper is concerned only with the ν_3 fundamental, expressions for the P and R branches alone will be given consideration.

The rotational constant, B, is given by the relation $B = \frac{h}{8\pi^2 Ic}$, where I is the moment of inertia of the molecule. Each energy level of the molecule can be considered to be made up of energy due to vibration and energy due to rotation. The energy may be represented in term form as $T = G(v) + F(J)$, where $G(v)$ is the portion arising from vibration and $F(J)$ is the portion arising from rotation. In the following discussion J' will refer to the rotational quantum number in the upper vibrational state and J'' to the lower. The frequency, ν, of a particular line in the P and R branches will be represented respectively by $P(J)$ and $R(J)$ where J refers to the rotational quantum number in the lower (initial) state.

The general expression (Herzberg, 1945) for the frequency can be written as

$$\nu = T' - T'' = G(v') + F(J') - G(v'') - F(J'')$$
$$\nu = \nu_0 + F(J') - F(J'')$$
$$\nu = \nu_0 + B'(J'+1)J' - D(J'+1)^2J'^2 - B''(J''+1)J'' - D(J''+1)^2J''^2,$$

where

$\nu_0 = G(v') - G(v'')$, B′ and B″ are rotational constants, and D is the centrifugal stretching constant. For simplicity $D' = D'' = D$ is assumed.

For the P branch the expression for the frequency has the following form:

$$P(J) = \nu_0 + F(J') - F(J'')$$
$$= \nu_0 + F(J''-1) - F(J'') \quad \text{since } J' = J'' - 1$$
$$= \nu_0 - (B' + B'')J'' + (B' - B'')J''^2 + 4DJ''^3.$$
$$J'' = 1, 2, 3, \text{——}$$

And for the R branch one may write

$$\begin{aligned} R(J) &= \nu_0 + F(J') - F(J'') \\ &= \nu_0 + F(J''+1) - F(J'') \quad \text{since } J'=J''+1 \\ &= \nu_0 + (B'+B'')(J''+1)+(B'-B'')(J''+1)^2-4\,D(J''+1)^3. \end{aligned}$$

$J''=0, 1, 2, 3, \text{——}.$

We note that there is no line in the P branch which corresponds to $J''=0$. The reason for this is readily seen from the fact that $\Delta J = -1$ in this branch. Thus the first line must originate from the transition $v'' = 0, J'' = 1$ to $v' = 1, J' = 0$. But the expression for the R branch permits the use of $J'' = 0$. The first line in this branch arises from the transition $v'' = 0, J'' = 0$ to $v' = 1, J' = 1$. The transition for ν_3 associated with $\Delta J = 0 (v''=0, J''=0$ to $v'=1, J'=0)$ is not a possible one but is used to denote the band center. The band center is defined as $\nu_0 = G(v') - G(v'')$

The expressions for $R(J-1)$ and $P(J+1)$ may be written and used with the expressions for $R(J)$ and $P(J)$ to form useful combination relations.

$$R(J)=\nu_0+(B'+B'')(J''+1)+(B'-B'')(J''+1)^2-4\,D(J''+1)^3 \quad (1)$$

$$R(J-1)=\nu_0+(B'+B'')J''+(B'-B'')J''^2-4\,DJ''^3 \quad (2)$$

$$P(J)=\nu_0-(B'+B'')J''+(B'-B'')J''^2+4\,D\,J''^3 \quad (3)$$

$$P(J+1)=\nu_0-(B'+B'')(J''+1)+(B'-B'')(J''+1)^2+4\,D(J''+1)^3 \quad (4)$$

In determining the value of ν_0 and $(B' - B'')$, the combination relation (Herzberg, 1945) $R(J-1) + J(J)$ may be formed.

From (2) and (3) above

$$R(J-1) + P(J) = 2\nu_0 + 2(B' - B'')\,J''^2$$

When a graph is plotted with $R(J-1) + P(J)$ along the vertical axis and J''^2 along the horizontal axis one obtains a straight line whose slope is $2(B' - B'')$ and whose vertical intercept is $2\nu_0$. Therefore a graph may be used to determine ν_0 and $(B' - B'')$.

The combination relation which is useful for determining B'' may be obtained by forming the combination

$$R(J-1) - P(J+1)$$

which is symbolized by $\Delta_2F(J'')$.

By combining (2) and (4), and simplifying one obtains

$$\Delta_2F(J'') = (4\,B''-6\,D'')(J''+\tfrac{1}{2}) - 8\,D''(J''+\tfrac{1}{2})^3,$$

where J'' is the rotational quantum number associated with the energy level from which a transition originates.

If $\Delta_2F(J'')/(J''+\tfrac{1}{2})$ is plotted along the vertical axis and $(J''+\tfrac{1}{2})^2$ along the horizontal axis one obtains a curve whose slope is $-8\,D''$ and whose intercept on the vertical axis is $4\,B'' - 6\,D''$.

The centrifugal stretching constant, D, is usually quite small and may often be neglected in finding the B values. If it is neglected we have $\Delta_2F(J'') = 4\,B''\,(J''+\frac{1}{2})$ which, upon plotting $\Delta_2F(J'')$ vertically and $(J''+\frac{1}{2})$ horizontally, gives a straight line with $4\,B''$ as its slope. Thus B'' is easily obtainable. In order to obtain a better relative (Herzberg, 1945) value of B' one usually obtains B'' from the relation $\Delta_2F(J'') = 4\,B''(J''+\frac{1}{2})$ and thence B' from $R(J-1)+P(J)=2\nu_0+2\,(B'-B'')J''^2$.

EXPERIMENTAL DATA

The ν_3 band was resolved in the first order with a grating of 7500 lines per inch. A reproduction of the band is shown in Figure 1. The slit width was equivalent to 0.5 cm^{-1} and the line spacing in the band was about 0.8 cm^{-1}. While it would have been very desirable to have a much smaller slit width, the width used was necessary in order to obtain sufficient energy for a run in the region of the spectrum investigated.

P Branch[2]		P Branch[2]		R Branch[2]		R Branch[2]	
1	2223.4 cm^{-1}	25	2201.4	0	2225.3 cm^{-1}	25	2243.8
2	2222.7	26	2200.4	1	2226.1	26	2244.5
3	2221.9	27	2199.4	2	2226.9	27	2245.1
4	2221.0	28	2198.5	3	2227.6	28	2245.7
5	2220.1	29	2197.3	4	2228.6	29	2246.4[3]
6	2219.1	30	2196.2	5	2229.2	30	2247.1
7	2218.3	31	2195.1	6	2230.1	31	2247.6
8	2217.5	32	2194.0	7	2230.8	32	2248.1
9	2216.6	33	2193.0	8	2231.5	33	2248.7
10	2215.7	34	2192.0	9	2232.3	34	2249.2
11	2214.8	35	2191.0	10	2233.2	35	2249.9
12	2214.0	36	2190.0	11	2233.9		
13	2213.0	37	2189.0	12	2234.7		
14	2212.0	38	2188.0	13	2235.3		
15	2211.1	39	2186.6[3]	14	2236.2		
16	2210.1	40	2185.3	15	2236.9		
17	2209.2	41	2184.6	16	2237.6		
18	2208.3	42	2183.2	17	2238.3		
19	2207.3	43	2182.0	18	2238.9		
20	2206.4	44	2181.0	19	2239.6		
21	2205.4	45	2179.8	20	2240.4		
22	2204.4	46	2178.7	21	2241.0		
23	2203.4	47	2177.7	22	2241.8		
24	2202.4			23	2242.5		
				24	2243.1		

[2]These values were obtained from measurements made in a vacuum and thus need no correction.

[3]Lines not observed.

The frequencies of the lines in the band were calculated using the expression $\nu = K\nu \csc \Theta$, where $K\nu$ is a constant of the grating and

Θ is the angle measured from the zero order position of the circle upon which the grating is mounted out to the position of the line under consideration. The results of the calculations appear in Table I.

The lines P39 and R29 were introduced into the table to keep the progression of line spacing. In the region of these two lines the appearance of the band made it impossible to identify the lines. However, this disturbance in the spectrum was not due to noise in the amplification system since the same pattern appeared again and again as new runs were made.

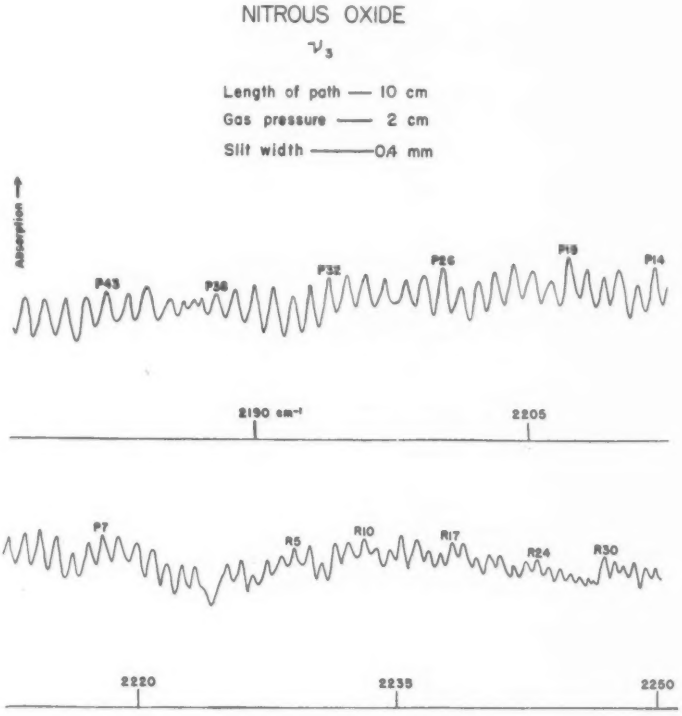

FIG 1

RESULTS AND CONCLUSIONS

A brief statement of the results is given in tabular form below.

(i) Lines in the P and R branches were identified with an accuracy of $\pm$ 0.1 cm^{-1}
(ii) $\nu_0 = 2224.4\ cm^{-1}$
(iii) $B'' = 0.4200\ cm^{-1}$
(iv) $B'-B'' = -0.00343\ cm^{-1}$

The intensity pattern of the spectrum was uneven. (See Fig. 1) This scalloped appearance was thought to be caused by the superposition of an upper stage band, i.e., one which arose from absorption by molecules which were initially in an upper energy level. An attempt to reduce the intensity of the upper stage band by cooling the gas was ineffective. The cooling system was not good enough to produce the change in temperature needed for an appreciable reduction in intensity of the upper stage band. Thus no definite conclusions were drawn concerning the nature of the phenomenon responsible for the uneven intensity pattern.

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Efficiency of the Thermoelectric Process

G. PRESTON BURNS
Physics Department, Mary Washington College of the University of Virginia

The efficiency of the thermoelectric process is defined as the ratio of useful electrical power output (W_o) delivered to an external load to the electrical equivalent of the thermal power absorbed at the hot junction of the thermoelements (W_i), that is,

$$\text{Efficiency} = W_o / W_i. \tag{1}$$

Maria Telkes (1947) derived a formula for the efficiency of the thermoelectric process using this definition. A revision of her derivation is given here on the basis of the following assumptions: (1) The theoretical efficiency is not influenced by the number of thermocouples; (2) lateral heat losses and Thompson heat are negligible; (3) the junction resistance is small compared to the total resistance of the couple.

Consider an operating temperature interval

$$\Delta T = T_h - T_c$$

and a single thermocouple. If e is the thermoelectric power of the couple then the open-circuit electromotive force is

$$E = e\Delta T. \tag{2}$$

When the circuit is closed through an external resistance (R_e) which is a constant (C'') times the internal resistance (R) of the thermocouple a current (I) will flow. This current is given by

$$I = \frac{1}{C''+1}\,\frac{E}{R}. \tag{3}$$

The potential drop across the load is

$$V_e = \frac{C''}{C''+1}\,E. \tag{4}$$

The power output is then

$$W_o = V_e I = \frac{C''}{(C''+1)^2}\,\frac{E^2}{R}. \tag{5}$$

The power loss within the thermocouple is

$$W = I^2 R = \frac{1}{(C''+1)^2}\,\frac{E^2}{R}. \tag{6}$$

From equations (5) and (6) the total electrical power produced in the thermocouple is

$$W_o + W = \frac{1}{C''+1}\,\frac{E^2}{R}. \tag{7}$$

A part of the thermal power (W_i) absorbed at the hot junction will be used for the production of ($W_o + W$) electrical power and part will be conducted away by the thermocouple elements. Call this latter quantity Q_c.

The amount of thermal power required to produce ($W_o + W$) electrical power is, by the second law of thermodynamics,

$$\frac{1}{C'' + 1} \quad \frac{E^2}{R} \quad \frac{T_h}{T_h - T_c}$$

This gives

$$W_i = \frac{1}{C'' + 1} \quad \frac{E^2}{R} \quad \frac{T_h}{T_h - T_c} + Q_c \tag{8}$$

and from equation (1)

$$\text{Efficiency} = \frac{W_o}{W_i} = \frac{C''}{(C'' + 1) - \dfrac{T_h}{\Delta T} + (C'' + 1)^2 \dfrac{Q_c R}{E^2}} \tag{9}$$

The electrical resistance of the elements is

$$R = \frac{P'l'}{A'} + \frac{P''l''}{A''} \tag{10}$$

and the heat conducted to or from each junction is

$$Q_c = \Delta T \left(\frac{k'A'}{l'} + \frac{k''A''}{l''} \right) \tag{11}$$

where p and k are the specific electrical resistance and specific heat conductivity of the elements l and A are the length and area, respectively. One prime indicates properties of one element and two primes properties of the other element.

By equations (2), (10) and (11)

$$\frac{Q_c R}{E^2} = \frac{\Delta T \left(\dfrac{P'l'}{A'} + \dfrac{P''l''}{A''} \right) \left(\dfrac{k'A'}{l'} + \dfrac{k''A''}{l''} \right)}{e^2 \Delta T^2} \tag{12}$$

Assuming that the resistance of one element is greater than that of the other and that more heat is conducted to or from a junction by one element than by the other we can write

$$\frac{P'l'}{A'} = C \frac{P''l''}{A''} \quad \text{and} \quad \frac{k'A'}{l'} = C' \frac{k''A''}{l''} \tag{13}$$

from which

$$P'k' = CC' P'' k''. \tag{14}$$

Substituting equations (13) in (12) and simplifying we get

$$\frac{Q_c R}{E^2} = \frac{P''k'' (C+1)(C'+1)}{e^2 \Delta T}. \tag{15}$$

Upon substituting equation (15) in (9) and simplifying the efficiency becomes

$$\text{Efficiency} = \frac{C''e^2\Delta T}{(C''+1)e^2T_h+(C+1)(C'+1)(C''+1)^2 P''k''} \tag{16}$$

By equation (14) we have chosen the constants C and C′ so that CC′ is the ratio of the products of the heat conductivity and electrical resistivity of the two elements of the couple. Call this D.

To determine the values of C and C′, considering the other quantities to be fixed values, which will maximize the efficiency in equation (16) it is necessary to make the product $(C+1)(C'+1)$ as small as possible.

Let

$$y = (C+1)(C'+1).$$

Then since $CC' = D$ (17)

we have $y = (C+1)(D/C+1)$.

Differentiating y with respect to C, equating the derivative to zero and solving for C, we get $C = D^{1/2}$ and from (17), $C' = D^{1/2}$. Hence, for the general case in which Pk is different for the two elements of the couple the thermoelectric process has the greatest efficiency when $C = C'$ for any given load.

If $C = C' = 1$, then equation (13) requires that the two elements of the couple have the same resistance and that they transfer equal amounts of heat to or from the junctions. It requires further that the product of the heat conductivity and electrical resistivity of the two elements of the couple be the same. Making this substitution in (16) we get

$$\text{Efficiency} = \frac{C''e^2\Delta T}{(C''+1)(e^2T_h) + 4(C''+1)^2Pk} \tag{18}$$

For this case for any given load it is necessary for maximum efficiency that the elements of the couple satisfy the Wiedemann-Franz-Lorenz ratio.

The power output as given by equation (5) is

$$W_o = \frac{C''}{(C''+1)^2} \frac{E^2}{R}.$$

To determine the maximum power output for a thermocouple, differentiate W_o with respect to C'', equate to zero, and solve for C''. This gives $C'' = 1$. Therefore, the thermocouple has its maximum output when the external resistance is equal to the internal resistance. Substituting this in equations (16) and (18)

$$\text{Efficiency} = \frac{e^2\Delta T}{2e^2T_h + 4(C+1)(C'+1)\ P''k''} \tag{19}$$

and

$$\text{Efficiency} = \frac{e^2\Delta T}{2e^2T_h + 16Pk} \tag{20}$$

Equation (19) gives the efficiency of the thermoelectric process when the output is a maximum for the case in which Pk for the elements of the couple is different and (20) gives the efficiency if Pk for the element is the same.

To determine the external load which will give maximum efficiency, differentiate (16) with respect to C'', equate the derivative to zero, and solve for C''. This gives

$$C'' = \frac{\sqrt{e^2T_h + (C+1)\ (C'+1)\ P''k''}}{\sqrt{(C+1)\ (C'+1)\ P''k''}} \tag{21}$$

and substituting $C'' = R_e/R$

$$R_e = R\ \frac{\sqrt{e^2T_h + (C+1)\ (C'+1)\ P''k''}}{\sqrt{(C+1)\ (C'+1)\ P''k''}}. \tag{22}$$

If Pk for the elements is different, then it is for this load that the efficiency of the couple is maximum. However, if $C = C' = 1$, then Pk for the two elements is the same and the load for maximum efficiency of the couple is

$$R_e = R\ \frac{\sqrt{e^2T_h + 4\ Pk}}{\sqrt{4\ Pk}}. \tag{23}$$

By making Pk as small as possible this load gives the maximum possible efficiency of the couple.

Equation (23) may be written

$$C'' = \frac{\sqrt{e^2T_h + 4\ Pk}}{\sqrt{4\ Pk}}. \tag{24}$$

Substituting (21) into (16) we get

$$\text{Eff} = e^2T_h / \left[e^2T_h + 2(C+1)(C'+1)P''k'' + 2\sqrt{(C+1)(C'+1)P''k''} + \sqrt{e^2T_h + (C+1)(C'+1)P''k''}\right] \quad (25)$$

and substituting (23) into (16)

$$\text{Efficiency} = \frac{e^2\Delta T}{e^2T_h + 8Pk + 4\sqrt{Pk}\quad\sqrt{e^2T_h + 4Pk}} \quad (26)$$

It may be observed that if Pk in equation (26) is zero, then

$$\text{Efficiency} = \frac{T_h - T_c}{T_h}$$

which is the efficiency of an ideal heat engine.

Summarizing, formulas have been derived for the efficiency of the thermoelectric process for the following cases:

(1) The general case in which the external load is different from the internal resistance of the generator, the resistances of the elements are different and the elements carry different amounts of heat to or from the junctions (Equation 16).

(2) External load is different from the internal resistance but the elements have the same resistance and transport equal amounts of heat to or from the junctions (Equation 18).

(3) Maximum power when resistance of the elements are different and the elements transport different amounts of heat to or from the junctions (Equation 19).

(4) Maximum power when the resistances of the elements are equal and the elements transport equal amounts of heat to or from the junctions (Equation 20).

(5) Maximum efficiency when the resistances of the elements are different and elements transport different amounts of heat to or from the junctions (Equation 25).

(6) Maximum efficiency when the resistances of the elements are the same and the elements transport equal amounts of heat to or from the junctions (Equation 26).

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News and Notes

(Editor's note: News contributions should be sent to the person whose name appears at the end of the appropriate section.)

SECTION NEWS

AGRICULTURAL SCIENCE SECTION

Wesley P. Judkins, Head of the Department of Horticulture at Virginia Polytechnic Institute, recently made a trip through the vegetable growing section of Eastern Virginia.

Each year the American Society of Agronomy recognizes certain of their members for outstanding achievements in the field of agronomy. This past year Samuel S. Obenshain of the Agronomy Department at Virginia Polytechnic Institute was one of twelve men recognized for his work by this Society.

Work has been carried out during the past seven years by the Agricultural Engineering Department at Virginia Polytechnic Institute to determine the relative effectiveness of contour pasture furrows, fertilization, and combinations thereof in the control of soil and water loss in pastures. The results of this study will be published soon.

L. I. Miller of the Tidewater Experiment Station, W. C. White of the Agronomy Department of Virginia Polytechnic Institute, and S. B. Fenne, Extension Plant Pathologist, Virginia Polytechnic Institute, are conducting a series of tests on seed treatments and inoculation studies with soybeans.

At the present time soil surveys are being made in several additional counties of Virginia. E. F. Henry is conducting the soil survey work in Norfolk County.

Progress is being made on the new addition to the main building at the Virginia Truck Experiment Station. Plans are for it to be ready for occupancy some time in July.

—T. J. NUGENT, P. O. Box 2160, NORFOLK

ASTRONOMY, MATHEMATICS AND PHYSICS SECTION

There have been several changes in the staff of the Physics Department of the University of Richmond. The Chairman of the Department is R. E. Alley, Jr. J. J. Taylor and E. C. Wingfield are members of the instructing staff.

J. W. Beams, Chairman of the Department of Physics of the University of Virginia, has announced that E. C. Stevenson will join the staff of Rouss Physics Laboratory in the near future. Mr. Stevenson

has had wide experience in both University work and Government research. Both the Nagasaki and Hiroshima bombs were assembled under his direction.

Two members of the Academy have recently joined the staff of the University of California Los Alamos Scientific Laboratory. They are Douglas Venable and J. H. McQueen. Mr. McQueen was a member of the Physics staff of the University of Virginia during the past academic year.

Blair B. Rhodes, Department of Physics of the Virginia Polytechnic Institute, is at present on leave, pursuing graduate study at the University of Pittsburgh.

Arthur Code has recently joined the staff of McCormick Observatory. Mr. Code received his training at the University of Chicago.

The Section Editor is particularly interested in any changes in personnel at the different schools in the State, and will appreciate greatly notices of such changes.

—I. G. FOSTER, VIRGINIA MILITARY INSTITUTE

BIOLOGY SECTION

Two committees have been formed in the Middle Atlantic Coast region for coordination of research activities. The Chesapeake Shad Research Committee consisting of William H. Massmann, Virginia Fisheries Laboratory; James Sykes, U.S. Fish and Wildlife Service; Coit Coker, Chesapeake Biological Laboratory; Galen Maxfield, Chesapeake Biological Laboratory; and Gerald Talbot, U.S. Fish and Wildlife Service are actively studying the life history and mortality of shad in the Chesapeake Bay. The Croaker Research Committee includes representatives from the same organizations, Dexter Haven, Virginia Fisheries Committee; Coit Coker, Chesapeake Biological Laboratory; and Eugene W. Roelofs, North Carolina Institute of Fisheries. These committees meet twice a year to plan future work and discuss results. Pooling of personnel from the various laboratories has made it possible to carry out projects on a broader scale than would have been possible individually.

The Virginia Fisheries Laboratory moved into its new laboratory buildings at Gloucester Point on June 1, 1950. The new site is just across the river from Yorktown on a bluff overlooking the lower York River. The present structures include a two story brick building and a small beach house for workshop and storage purposes. A 300 foot pier provides docking facilities for moderate-draft boats.

The laboratory building includes areas for research and teaching as well as an exhibit room for the public and two small dormitory rooms for housing summer students and visiting investigators. Adequate facili-

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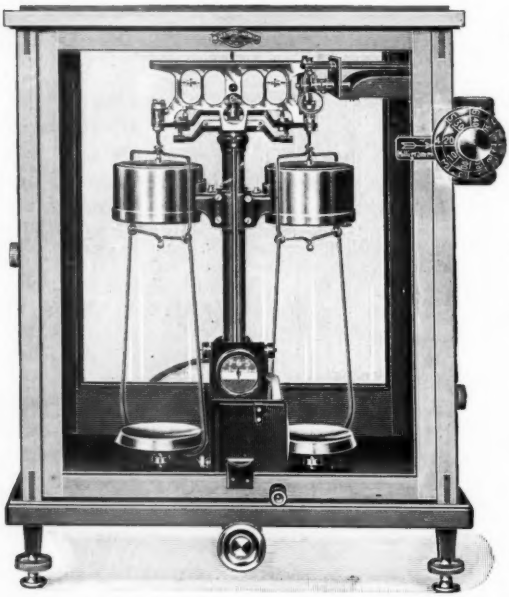

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ties for most types of marine and brackish water research are available, including running salt water, a constant temperature room, and research offices and cubicles. Close associations with the College of William and Mary and the Department of Biology of the College add to the social and research opportunities at the Laboratory. Students or independent investigators interested in working at the Laboratory should write the Director, Virginia Fisheries Laboratory, Gloucester Point, Virginia.

—LADLEY HUSTED, UNIVERSITY OF VIRGINIA

CHEMISTRY SECTION

The Virginia Section of the American Chemical Society has announced the following Distinguished Service Awards:

For outstanding contributions toward improvement of the professional standing of chemists: Garnett Ryland, Professor Emeritus at the University of Richmond, for twenty-eight years head of the Department of Chemistry there.

For contributions toward the stimulation of interest in high school chemistry: William I. Nickels, Jr., former science teacher, now principal of Lane High School in Charlottesville.

Recent publications from the University of Virginia include the following:

Robert E. Lutz and J. S. Gillespie, "Reduction of Unsaturated 1, 4-Diketones by Aluminum Isopropoxide," *Journal of the American Chemical Society*, 72, 2344 (1950); "1-4-Reduction of Unsaturated 1, 4- Diketones by Lithium Aluminum Hybride," *ibid.*, *72*, 2002 (1950).

Robert H. Jordan and Robert E. Lutz, "The Preparation of 4-Ethyl-2-methoxy-2-phenylmorpholine," *ibid.*, *72*, 1409 (1950).

Alfred Burger and Charles R. Walter, "Some Alpha-Substituted. Beta-Pyridylethylanines," *ibid.*, *72*, 1988 (1950).

Robert E. Lutz, Thad Amacker, Spencer King, and Newton Shearer, "Amines and Imines of 1,4-Diaryl Unsaturated 1,4-Diketones, *Journal of Organic Chemistry*, *15*, 181 (1950).

James W. Cole, Jr., John M. Chilton, and Preston H. Leake, "An Inexpensive Instrument for Electrometric Measurements," *Journal of Chemical Education*, 1950.

John H. Yoe, "Inorganic Analysis with Organic Reagents," Chapter II, Volume VII, of *Frontiers in Chemistry*, published under the auspices of Western Reserve University by Interscience Publishers, Inc., New York, 1949.

Dr. Yoe presented a paper on "Colorimetric Analysis" at the United States Technical Conference on Air Pollution, held in Washington on May 3, 4, and 5. The meeting was called by President Truman to con-

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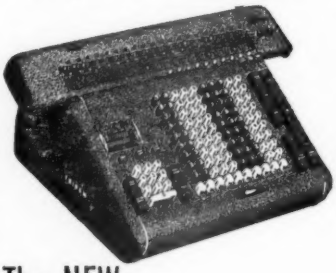

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sider the pressing problem of atmospheric contamination. The delegates included several from foreign countries.

Allan T. Gwathmey, of the University of Virginia, participated in a conference on "The Fundamental Aspects of Lubrication," sponsored by the New York Academy of Science on March 3 and 4. He reported on studies of the action of hot oils and gases on single crystals of metals and on friction and wear between single crystals. On June 8-10, he attended the Symposium on Thin Films, at the Armour Research Foundation in Chicago. He served as chairman of the round table discussion on the tenth.

Two recent graduates of the University of Virginia will begin work at Oak Ridge on August 1. Fred Young, whose dissertation was concerned with "The Rate of Formation of Tarnish Films on Metal Single Crystals as Determined by Interference Colors and Polarized Light," will become a Research Participant at the Institute for Nuclear Studies. George Pedro Smith will become a regular employee of the Oak Ridge National Laboratories. His doctoral studies were related to "Sinterning or Bonding between Metal Single Crystals."

To receive the first William Ralston Memorial Award for Excellence in Scientific Writing, the society selected Harold G. Breeden, senior in chemical engineering at the University of Virginia.

In connection with the Ralston Award, honorable mention was given to Richard G. Canham, College of William and Mary; Robert H. Hill, Virginia State College; Myron M. Yagel, University of Richmond; Jack B. Perkins, Randolph-Macon College; and Neal T. Levin, University of Virginia.

Lynn D. Abbott, Jr., Medical College of Virginia, was elected chairman of the Virginia Section for the year 1950-1951. William G. Guy, College of William and Mary, and Mary E. Kapp, Richmond Professional Institute, were elected chairman-elect and vice-chairman respectively. Elected secretary was Kenneth C. Bass, Jr., duPont Company, Richmond, and treasurer, Clinton W. Baber, Larus and Brother Company. —WILLIAM E. TROUT, JR., BOX 168, UNIVERSITY OF VIRGINIA

ENGINEERING SECTION

The Ronald Press Company, New York City, has recently announced the publication of "Electronics—Principles and Applications" by Ralph R. Wright, Associate Professor of Electrical Engineering, Virginia Polytechnic Institute.

This book, which gives a broad coverage of the basic applications of electron tubes in the fields of communication, industry and control, is designed to serve as a text book for a basic course in electronics. Rather

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than stressing mathematical derivations and detailed electronic circuit analysis, the author has given a sound grounding in the principles of electronics and an understanding of how these principles apply to practical circuits. —NELSON F. MURPHY, VIRGINIA POLYTECHNIC INSTITUTE

GEOLOGY SECTION

The second annual Southeastern States Mineral Resources Symposium was held at Lexington, Kentucky, March 23-25, with geologists and engineers from eleven states attending the technical sessions. Vincent E. Nelson, Department of Geology of the University of Kentucky, was in charge of the program which was highlighted by an evening address delivered by W. E. Wrather, Director of the U.S. Geological Survey. A delegation from the Geology Department at Virginia Polytechnic Institute attended this meeting. The 1951 symposium will be held at Emory University in Atlanta.

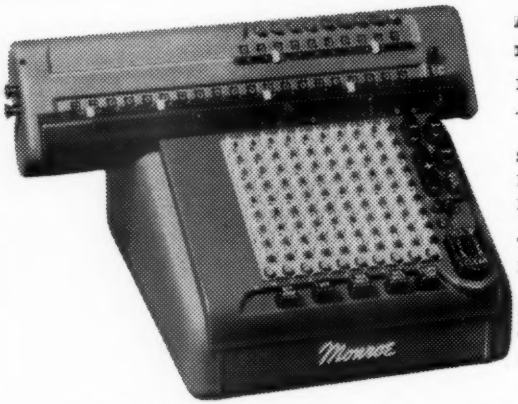
On April 16, the Virginia Department of Highways sponsored a regional symposium on geology as related to highway engineering. More than 250 geologists attended this meeting held in Richmond, directed by William T. Parrott, engineering geologist of the Department of Highways. The program created considerable discussion and much enthusiasm. It was the consensus of those present that similar programs should be continued on an annual basis with the active participation of interested engineers and geologists in neighboring states.

Two geologists are being added to the Department of Geology at Virginia Polytechnic Institute. Wayne E. Moore of Cornell University joins the staff on September 1, and Gilbert L. Hole of Columbia University will replace C. E. Sears who will take leave of absence during 1950-52 for pursuance of a graduate program in geophysics at Colorado School of Mines. Mr. Hole will assist Dr. Cooper and Dr. Lowry at the Virginia Polytechnic Institute Geology Summer Camp which convenes August 2 to September 9.

—BYRON N. COOPER, VIRGINIA POLYTECHNIC INSTITUTE

PSYCHOLOGY SECTION

Several psychologists from the state attended the meetings of the Southern Society for Philosophy and Psychology in Nashville on April 6-8. D. M. Allan was elected Secretary of the Society, of which R. H. Henneman is Treasurer. W. M. Hinton invited the Society on behalf of Washington and Lee University to hold its 1951 meetings in Roanoke. This invitation was accepted. It is hoped that a large number of Virginia psychologists will plan to attend these meetings in the spring of 1951.



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On the psychology staff at the University of Virginia Summer Session will be three visiting professors: W. M. Hinton of Washington and Lee University; J. M. Proter of Rensselaer Polytechnic Institute; and R. C. Wingfield of Converse College.

The Society of Experimental Psychologists will hold its 1951 meetings at the University of Virginia. This will be one of the very rare occasions when this Society has held its meetings at a Southern institution.

The *American Psychologist* featured as its lead article in the May issue "The Ph.D. Program in Experimental Psychology at the University of Virginia." This article was prepared, on invitation from the Editor, Helen M. Wolfle, by the staff of the University's Department of Psychology.

Richard H. Henneman attended an international conference on speech communication on May 31-June 3 in Boston. This conference was sponsored jointly by the Acoustical Society of America, the Massachusetts Institute of Technology, and the Harvard Psycho Acoustic Laboratory.

Section Chairman, John N. Buck, reminds all members of the Psychology Section that much confusion and inconvenience will be avoided by the payment of Academy dues to the Section Secretary-Treasurer, Stanley B. Williams, of the College of William and Mary.

RICHARD B. HENNEMAN, UNIVERSITY OF VIRGINIA

STATISTICS SECTION

R. A. Bradley, who received his Doctor's Degree at the University of North Carolina and who is now at McGill University, will join the staff at Virginia Polytechnic Institute as Associate (research) Professor of Statistics.

F. W. Cleaver received his Master of Science Degree in Statistics from Virginia Polytechnic Institute.

Leonard Cooper, a recent graduate of Bridgewater College, has accepted a Bureau of Agricultural Economics fellowship at Virginia Polytechnic Institute in Statistics.

David Duncan, who received his Doctor's Degree at Iowa State College and is Senior lecturer of the University of Sydney (Australaia), has accepted an appointment as Associate Professor of Statistics at Virginia Polytechnic Institute, and will join the staff the first of September.

Robert Horn has been awarded a tuition scholarship to work on subjective tests in the Department of Statistics at Virginia Polytechnic Institute as of September.

Boyd Harshbarger, former president of the Virginia Academy of

Science, received the alumni award as the outstanding Bridgewater College alumnus of the past year.

Ira DeArmon, formerly with the Virginia Health Department, is now statistician with the Medical Division of the Army Chemical Center, Maryland.—WALTER A. HENDRICKS, 6901 ARLINGTON ROAD, BETHESDA, MARYLAND

[*July*

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